N 71 12115

CR 111375

AMERICAN SCIENCE AND ENGINEERING

1 OCTOBER 1970

ASE-2527

11 CARLETON STREET, CAMBRIDGE,
MASSACHUSETTS 02142 (617) 868-1600

FINAL REPORT

HARD X-RAY EXPERIMENT FOR ASTRONOMICAL NETHERLANDS SATELLITE (ANS) PROGRAM

CONTRACT NASW-2001

PREPARED FOR

NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
CODE SG: ASTRONOMY BRANCH
WASHINGTON, D. C. 20546

ASE-2527

Final Report:

HARD X-RAY EXPERIMENT FOR ASTRONOMICAL NETHERLANDS SATELLITE (ANS) PROGRAM

Contract: NAS W-2001

Submitted to:

National Aeronautics & Space Administration
Code SG: Astronomy Branch
Washington, D.C. 20546

By:

American Science & Engineering, Inc.
11 Carleton Street
Cambridge, Massachusetts 02142

1 October 1970

Approved: S. Felix

S. Felix
Program Manager

PREFACE

American Science & Engineering, Inc., (AS&E) has conducted a preliminary design study activity under NASA Contract NAS W-2001.

The results of the studies performed were outlined in the contractual mid-point report, Document ASE-2469, dated July 1970, and comprehensively detailed in Volumes I & II of Document ASE-2477, entitled, "Hard X-Ray Experiment for Astronomical Netherlands Satellite (ANS) Program." These volumes now constitute Part I (Technical Discussion) and Part II (Program Management) of this report.

AS&E has also prepared a preliminary Structural-Thermal Model drawing (SK 135-003) and a preliminary Interface Control Drawing (SK 135-113, Rev. A). A preliminary PERT network has also been prepared, outlining the basic programming events of the next phase of the program. Photoreductions of the drawings and the PERT network may be found in PART III of this report.

The above-mentioned documentation will constitute the final report of NASA Contract NAS W-2001.

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

PART II. PROGRAM MANAGEMENT

CONTENTS (Cont'd)

PART I. TECHNICAL DISCUSSION

1.0 SCIENTIFIC OBJECTIVES

1.1 Hard X-Ray Experiment Specification

The AS&E/MIT Experiment aboard the ANS will consist of two Bragg diffraction spectrometers to detect line emission from highly ionized atomic states, and two large area detectors (LAD) to (1) detect x-rays, (2) analyze them into spectra, (3) record the arrival time of each x-ray for pulsar observation and (4) provide pointing error signal for the Bragg experiment.

The scientific objectives are as follows:

(1) Detect faint sources

(2) Measure the spectral content of the stronger sources in the interval 2 - 40 keV,

(3) Observe the surface brightness of extended sources by scanning with the slit field-of-view,

(4) Detect line emission from the stronger sources,

(5) Observe time variation of two types: pulsar and slow variability over a two-day period, and

(6) Measure x-rays simultaneously with ground-based optical or radio astronomers for a correlated observation.

1.2 Measurement Processes

Choice of Observations

A sample observing program is included in the appendix of the technical proposal. It was made for the prupose of coordinating our observations with the other experimenters. In order to best choose observations during the actual mission, we will maintain a file of sources found in all-sky surveys conducted over the next several years. In addition we will include a file of known pulsars and other interesting astronamical objects which may be desirable to observe. To this we will add guide stars and other information pertinent to our observations. The six types of observations are described below.

Detection of Faint Sources

The purpose of this measurement is to check for x-ray emission from specific objects. Because the pointed capability of the ANS permits us to observe one source for more than two days, we are sensitive to weak sources even though the detector area is not very large. One day's observation would allow the existence of x-rays to be determined from a source as weak as 5×10^{-4} counts/cm^2-sec. We would choose to observe interesting objects not seen in x-rays before. Moreover, this type of observation would verify x-ray emission from sources seen at the limit of sensitivity of all-sky survey experiments prior to the ANS mission.

Spectral Content Measurement

The large area detectors will yield 15-channel energy spectra with resolution of 1 to 6 keV over the energy range 2 - 40 keV. A background measurement for equal time will be required also. The spectral hardness and low energy cutoff can be determined if the counting rate in each channel after background substraction is measured to about 3%.

The measured parameters will lead to a choice between a thermal brehmsstrahlung source and a synchrotron source. An extrapolation of the known sources indicates that there may be about 100 sources strong enough (> 10^{-2} counts/cm^2 sec) for a spectral content measurement.

Surface Brightness of Extended Region

The variation of source strength with position in one direction (ecliptic latitude) can be determined by stepping the slit field-of-view across an extended source. Each step 10' apart would actually represent two 5' steps because of the offset of the two LAD collimators. An extended source of width $1/2^{\circ}$ and total intensity 3×10^{-2} counts/cm^2-sec could be mapped in one day.

Detection of Line Emission with Bragg Crystal Spectrometer

The most promising emission line regions are either Si^{+12}, Si^{+13} or S^{+14}, S^{+15}. These lines would appear strongly in the spectrum of a source of temperature 1.5×10^7 °K, whereas the Fe^{+24} and Fe^{+25} lines would appear strongly from a 7×10^7 °K source. At present, the knowledge of the temperature of a few sources indicates that greater sensitivity is desired on the 1.5×10^7 °K region. Further theoretical work will determine just which of these pairs will be chosen for the Experiment.

In the normal mode of operation, the satellite will be pointed to within about 1' of the source. It is assumed that the crystal will be compatible with the pointing accuracy. For the stronger x-ray sources it will be possible to scan the energy region containing the line by varying the Bragg angle through the use of the offset capability of the spacecraft. This will allow, for example, measurements of line broadening and line shifts which are consistent with the resolution of the spectrometer. Data will be accumulated and the procedure outlined in Section 1.1 will be used to identify the lines. We estimate that 26 of the presently know x-ray sources are strong enough (>.14 counts/cm^2-sec) for one day's observation to detect a line which represents 0.3% of the total x-ray flux.

Observation of Time Variability

Three possible modes of pulsar observation have been considered:

A. Time-Tagging Each Photon

This mode permits all analysis to be performed on the ground where corrections can be made for subtle effects such as phase change due to orbital position. It is limited by the data storage capability of the on-board computer which permits at most 16,000 counts.

B. On-Board Photon-Photon Autocorrelation

In this method counts are accummulated for a short time and the onboard computer performs the autocorrelation calculation which compresses the data allowing for storage of many more counts than method A. While this method may be very sensitive, any information on the shape of the pulse is lost, and an accurate determination of the period is impossible.

C. On-Board Cross-Correlation with a Clock

This mode requires a very stable on-board programmable clock and it could not correct for phase change due to orbit position.

At the present time methods A and B are being considered to see which one promises higher performance under the constraints of the onboard computer and the telemetry readout.

Two types of objects are worthy of pulsar observation. The first are objects from which pulses have been seen at other wavelengths. Data analysis is simplified in this case because the period is known beforehand. The second are known x-ray sources of other interesting objects from which no pulsation has been observed. In this case it is necessary to make a search for the period, possibly covering as many as 1 million steps. Careful attention must be paid to the statistical significance of the result since a steady source may appear like a pulse due to statistical fluctuations when analyzed according to so many different periods.

Slow time variations are observable also by dividing the total time a source is observed into segments and comparing the count rate. A time scale of up to two days is possible. For very strong sources, the high rate mode (readout every 4 sec) would be used to detect variability over a short time scale.

Correlated X-Ray - Optical - Radio Observation

An x-ray source is positively identified with a particular optical or radio counterpart if intensity variations are seen simultaneously.

Long before launch a careful choice must be made of which sources to observe in this way because of the extensive preparation necessary to schedule the optical or radio observation.

1.3 Data Handling

While this proposal does not require the definition or the plans associated with data analysis during and subsequent to the actual mission, the following represents some of the thoughts given to that phase of the program.

The data must become available for analysis by AS&E scientist as soon as possible after it is relayed from orbit. On possible scheme is to divide the data into two parts: the quick-look data and the remainder. The quick-look will consist of all the data from 2 orbits each day which will be relayed to AS&E by data-link in no more than 2 days. This will be used to verify satisfactory operations of our experiment and to begin the analysis. The remaining data will follow on tape reels sent by mail to be received at AS&E no more than 1 month after being telemetered from orbit.

The data analysis will consist of the following steps to be done w ith the aid of our IBM 360 computer:

(1) Sum all data for a particular source,

(2) Remove data from time intervals in which radiation belts are encountered or the pointing wanders excessively,

(3) Subtract background,

(4) Obtain spectra and generate best-fit parameters,

(5) Divide data into time intervals to look for time variation,

(6) Sort pulsar counts into time bins and search for period if unknown,

(7) Find Bragg peak and subtract continuum spectra,

(8) Sort into position steps if stepping mode used, and

(9) Look for sources in scan mode.

2.0 SYSTEM DESCRIPTION

This section summarizes the systems aspects of the Hard X-Ray Experiment. It includes a functional description of the instrument and the commandable modes of operation. The principal experiment/spacecraft interface requirements are listed and discussed in detail where pertinent. The ground support equipment is discussed in Section 5.0, and the testing, calibration, integration and field support phases of the program are described in Section 6.0.

2.1 Experiment Description

The proposed package consists of two instruments, namely, the Large Area Detector (LAD) and the Bragg Crystal Spectrometer (BD). The Large Area Detector measures x-ray emission from selected objects and regions in the energy range of 2-40 KeV using narrowly collimated proportional counters. The Bragg Crystal Spectrometer will measure two emission lines in the Si to S energy range using Bragg Crystals and collimated proportional counters. A pictorial illustration of the Astronomical Netherlands Satellite is shown in Figure 2-1. The Hard X-Ray Experiment configuration is shown in Figure 2-2 of this proposal.

2.2 Major Elements of Hardware

The experiment is contained in a single package and consists of five major elements of hardware in addition to the housing. Some of the important features of each element are mentioned below.

Detectors

Large Area Detectors (LAD) - The large area array consists of two collimated proportional counters of about 86 cm^2 each. This area is reduced to an effective area of 35 cm^2 each by the loss due to window structure and by the 50% collimator transmission.

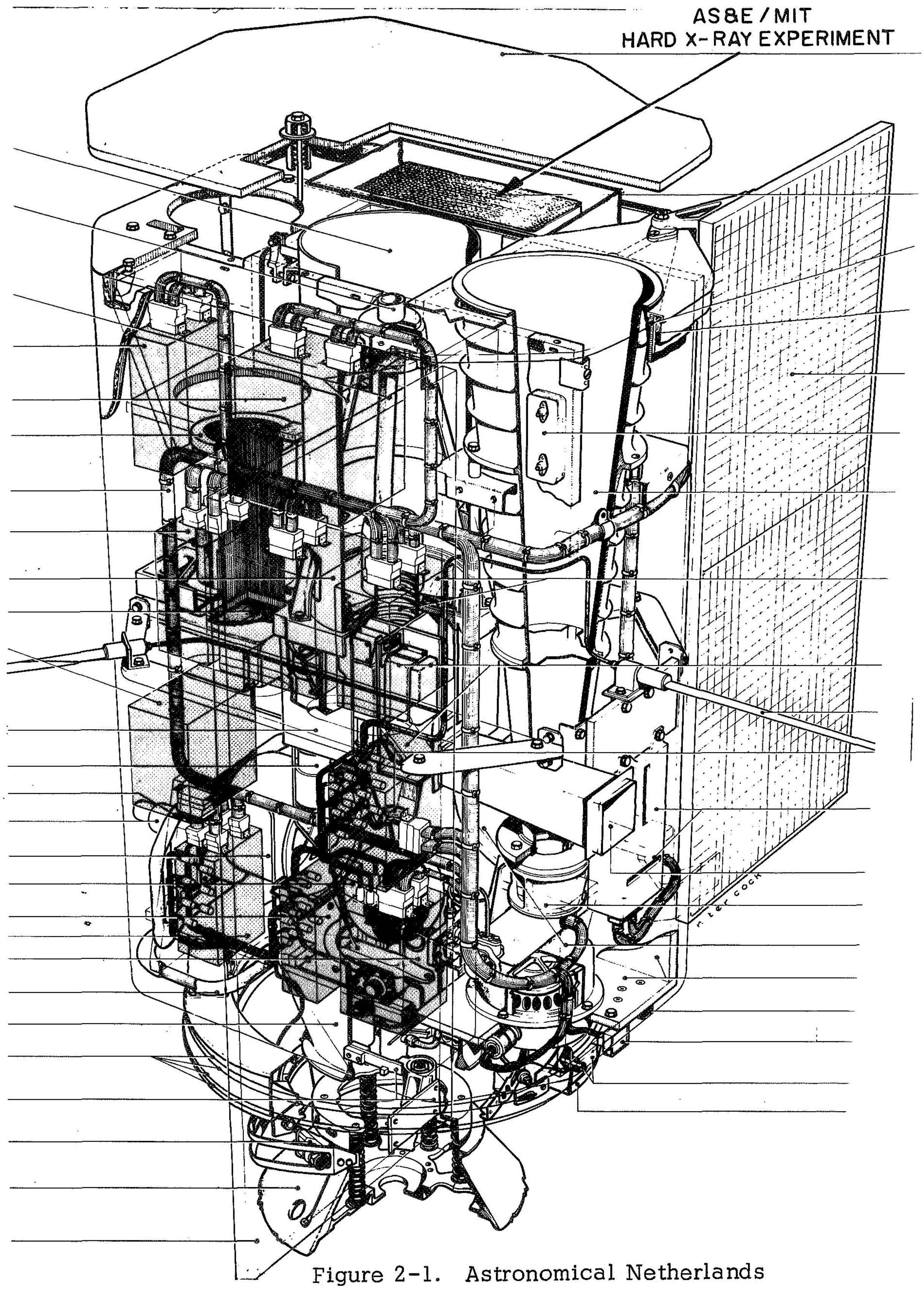


Figure 2-1. Astronomical Netherlands Satellite Configuration

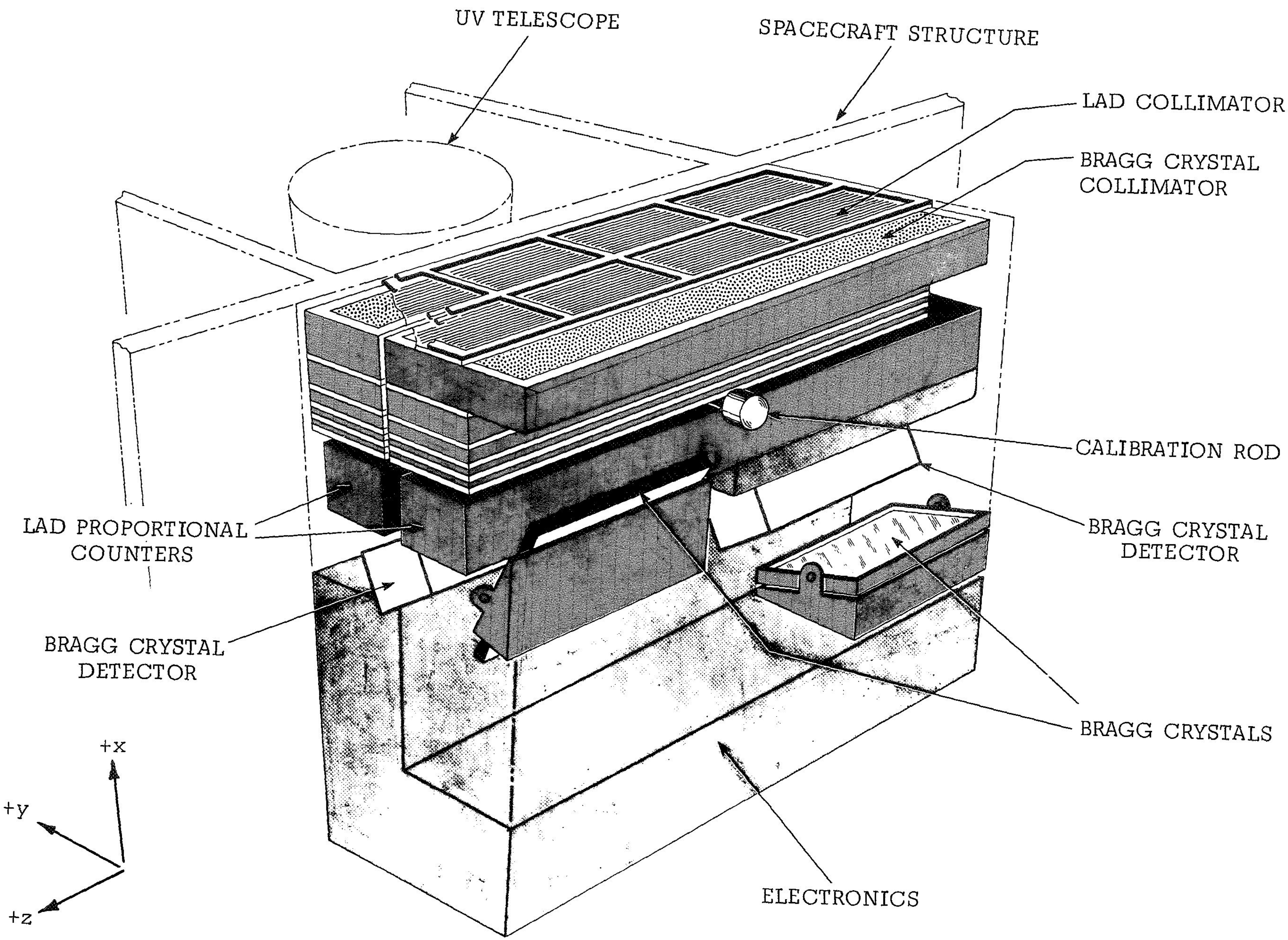


Figure 2-2. Configuration of ANS Hard-X-Ray Experiment

The two detectors are offset to allow for azimuthal referencing on strong signals. Each detector has 10' x 3^{o} field-of-view, but the center angles are offset by 5' giving a composite 15' x 3^{o} field and allowing for differences in counting rates to provide the azimuthal reference. As the system is presently proposed, the difference in counting rates can only be obtained by data processing of the output of the high rate LAD accummulators using the on-board computer. The combined detector area is somewhat reduced, being only 52.5 cm^2 instead of 70 cm^2. Usage of the azimuthal reference as an error signal for the attitude control subsystem is presently being studied.

Proportional Counters

The proportional counters for the LAD must maintain high efficiency over the 2 - 40 keV range. For this reason the best choice of fill gas is xenon at about 900 mm pressure to which a small percentage of quench gas is added. The counter and 3-mil-thick window are to be constructed of beryllium. The LAD and proportional counters used to detect the diffracted x-rays in the Bragg spectrometer will be laboratory tested in order to achieve best performance with the constraint of using the same value of high voltage for both types of detectors.

Bragg Crystal Spectrometer System

Spectrometer - A number of crystals are suitable for studies of line emission in the Si - S energy range and Tables 2.0 a & b list their properties. Initially, samples of these crystals will be studied for compatibility with the mission requirements. The exact choice of crystal will depend, in part, upon the pointing accuracy and stability of the spacecraft, which may, in turn, depend upon the distribution of guide stars in the vicinity of the target x-ray object. Compacted graphite, because of its broad rocking curve,

Table 2.0a. Bragg Angles for Si and S Line Emission for a Variety of Crystals

Line	E (keV)	λ (Å)	Mica (19.98)	Fluorite CaF_2 (10.93)	ADP (10.64)	EDDT (8.803)	PET (8.75)	Topaz (8.389)	Compacted Graphite (6.708)	Quartz SiO_2 (6.686)	Ge (6.54)	Fluorite CaF_2 (6.32)	Si (6.271)	Calcite $CaCO_3$ (6.070)	NaCl (5.641)
Si^{+12}	1.86	6.67	42.3 (3)	37.6	38.8	49.1	49.7	52.6	83	----	----	----	----	----	----
Si^{+13}	2.00	6.20	38.8 (2)	34.6	35.6	44.6	45.2	47.7	68.7	----	----	----	----	----	----
S^{+14}	2.42	5.12	50.8 (3)	27.9	28.8	35.6	35.8	37.6	49.7	50.0	51.5	54.2	54.8	57.6	65.4
S^{+15}	2.61	4.75	46.1 (3)	25.8	26.5	32.5	32.8	34.5	45.2	45.3	46.6	48.7	49.2	51.5	57.3

Table 2.0b. Crystal Properties at CU Kα

Crystal	Plane	2dA	Order	Surface	R_c	R_p	Rocking Curve FWHM (Seconds of arc.)
PET	(001)	8.742	1	cleaned & polished	$1.1x10^{-4}$	27	55
EDDT	(010)	8.808	1	polished	$1.2x10^{-4}$	31.5	40
				ground	$8.6x10^{-5}$	32	29
Graphite		6.708	1		$1x10^{-3}$	10	
Quartz	(1011)	6.686	1		$2x10^{-5}$	78	
Gevmann	(111)	6.54	1		$8x10^{-5}$	80	
Calcite	(100)	6.070	1		$4x10^{-5}$	70	

is good for situations where pointing accuracy is poor. The rocking curve is much broader than the natural line width of the emission lines and the pointing could drift as much as $\pm$ 1/4 degree before the crystal drifts out of the allowable Bragg angle range. The peak reflectivity of compacted graphite is poor, however, and this constrains the minimum detectable source to a higher value. For highly accurate pointing, crystals with very narrow rocking curves can be used (Ge, Si) and good use can be made of their higher peak reflectivities.

Two crystals, one for each line, will be used. Each crystal will have a projected area of about 20 cm^2 and independent proportional counters will record x-rays reflected from each crystal. The data will be recorded in eight pulse height bins with the desired emission line energy corresponding to one of them. The presence of a line will be indicated by the detection of a significant increase in counting rate in the singal bin corresponding to the line. Since the large detector array and the Bragg spectrometer are co-aligned, it will be possible to estimate (through the use of previous cross-calibrations) the number of photons to be expected from the source continuum and, hence, it will be possible to identify a significant departure in the signal channel.

<u>Proportional Counter Detectors</u> - These detectors will be designed to have a high efficiency near the Si or S lines. One atmosphere of neon or argon in a 2-cm-deep counter is 85% efficient at about 2.0 keV, while 1.5 atmospheres of pressure is about 80% efficient at 2.5 keV. The counters will have 1-mil Be windows which are about 70% and 80% transmitting at 2.0 and 2.5 keV. The net detection efficiency will be about 60% in either case. Background suppression will be either by pulse shape discrimination or a

combination of both pulse shape discrimination and anti-coincidence with a second anode wire or guard counter. It should be possible to reduce the background counting rate to 0.1 counts/sec. in each detector.

Asymmetrically Cut Crystals - The possibility or narrowing the width of the reflected beam exists. This is accomplished by cutting the crystals in the manner illustrated in Figure 2-3. A smaller detector and increased sensitivity are gained in this method. During the initial phase of the program, a variety of asymmetrically cut crystals will be tested in order to determine the efficacy of this procedure. If the concentration ratio is C (defined as $C = W_o/W$, where W_o and W are defined as the indicent and reflected beam widths respectively), then the minimum detectable source strength is lowered by C. A practical value for C is 10. Thus, if there are no difficulties in applying the technique, the minimum detectable source will be lowered by a factor of 3.

Pulse-Shape Discrimination

This is a technique of discriminating between real x-ray and γ-ray background events in the porportional counter. By setting a time window the long risetime γ-ray can be rejected. The aim is to reject 90% of the γ-ray while accepting 90% of the x-rays in the 2 - 40 keV interval. The risetime properties of xenon-filled counters are not so well known as those of the argon-filled counters previously used by AS&E to cover up to 20 keV. The choice of quench gas and PSD time window will be based on x-ray and gamma-ray radiation tests made with counters similar to those to be flown.

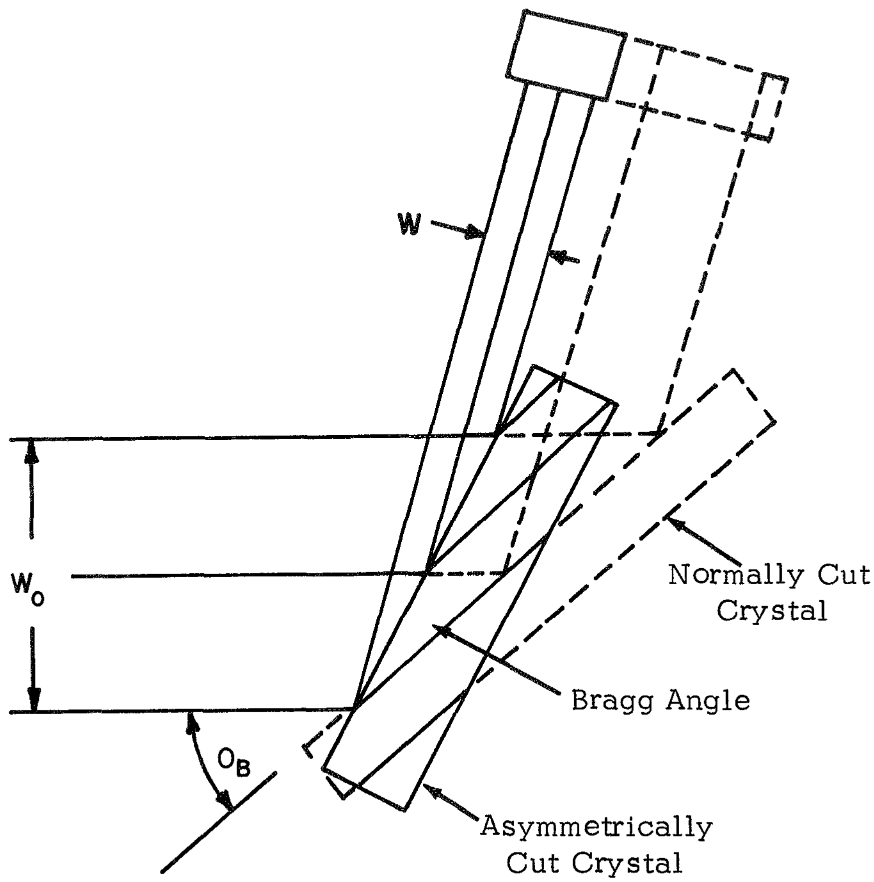


Figure 2-3. Asymmetrically Cut Crystal Arrangement
to Narrow Width of Reflected Beam

Collimators

LAD Collimator - A wire grid collimator consisting of six wire planes is mounted in front of the Large Area Detector. This collimator has a slit field of view of 10' FWHM. In addition the field-of-view is restricted by a tube-type collimator of 3^{o} FWHM so that the net field of view is 10' x 3^{o}.

BD Collimator - The tube-type collimator will be used to provide a 3^{o} FWHM field-of-view. The optical centerlines of the LAD collimator and the BD Collimator are aligned to within 1 arc-minute.

Calibration Sources

Radioactive calibration sources are mounted on rods in front of each detector and are activated by rotary solenoids. The sources are rotated into position on command for a short period of time and thus provide an end-to-end calibration of the system. Typical sources that can be used are Fe^{55} for the BD and Am^{241} for the LAD.

Electronics

The electronics subsystems are described in detail in the Electronic Design section. In summary, the electronics consists of power and command distribution, low and high voltage power supplies, solenoids and associated drivers to operate the calibration rods, and analog and digital signal-processing circuitry. The major elements of the signal-processing circuitry are: an analog preamplifier for each detector, a summing amplifier, a pulse-shape discriminator, two window discriminators, a 15-channel pulse-height analyzer, 34 accumulators (eighteen 16-bit accumulators and sixteen 8-bit accumulators) and various digital circuitry used for control of inputs to and outputs from the accumulators.

2.3 Operating Modes

The experiment has two switched modes of operation; namely, the Normal Mode and the Pulsar Mode. Data is collected by the Large Area Detectors and the Bragg Detectors in both operating modes. The pulsar mode provides data on the time of occurence of individual pulses with a precision of one millisecond. All variations of the two modes in terms of data retrieval, memory requirements, observing time and attitude control as described in the observational program (Appendix A) are controlled by the on-board computer. In-flight calibration is also described.

Normal Mode

Functionally, the experiment operates in the Normal Mode as described below.

X-Ray photons passing through the proportional counter beryllium window ionize the gas inside by an amount proportional to their energy. A very stable high-voltage power supply provides a bias voltage for operation of the proportional counters. The high voltage across the counters produces an electric field gradient and, hence, a multiplication effect which results in a charge output that is proportional to the X-Ray energy. The charge-sensitive preamplifier associated with each counter converts the input charge to an output pulse which has a fast rise-time, a slow decay, and an amplitude proportional to the x-ray energy.

The processing of the data is shown in a functional block diagram in Figure 4-1. The pulse received from the charge-sensitive preamplier is amplified locally. The outputs from the four preamplifiers are routed to a common summing amplifier and a detector identification circuit. The use of a common summing amplifier is

permissible because the probability of pulses occurring simultaneously in two or more detectors as packaged is remote. In addition, the LAD outputs are routed to separate single energy window discriminators associated with the two high rate LAD accumulators

The summing amplifier multiplexes the four signals to a single pulse-shape discriminator and a 15-channel pulse-height analyzer (PHA). The pulse-shape discriminator measures the rise-time of the pulse to distinguish between x-Ray and background pulses. The background count has a longer ionization time in the proportional counter, thereby producing a pulse with a longer rise-time. A veto singal is generated if the measured rise-time exceeds the r reference time determined for x-rays indicating a background count rather than an X-ray count received. The veto signal inhibits further processing of the background. If no veto signal is present, the pulse amplitude is analyzed by the 15-channel PHA and stored in the appropriate accumulator. Also, if the x-ray event originated in one of the large area detectors, the signal is processed by the associated window discriminator to increment a high rate LAD accumulator.

The PHA resolves outputs from the two large area detectors taken together into 15 energy channels and outputs from the two Bragg Detectors taken separately into eight energy channels. The detector identification circuit indicates the source of the pulse and provides control signals to the PHA and the Accumulator Input Control to enable the appropriate 8-channel (BD 1 or 2) or 15-channe (LAD 1 or 2) mode of the PHA and to form part of the address which when combined with the output of the PHA, will increment the appropriate accumulator. In all, the Experiment Scientific Data are contained in 34 accumulators consisting of eighteen 16-bit accumulators and sixteen 8-bit accumulators. The data con-

figuration and proposed sampling rates are given in Table 2.1. The LAD data is contained in fifteen (address 0-14) 16-bit accumulators. The Data from each BD are contained in eight (address 16-23) 8-bit accumulators. The corresponding BD accumulators are combined for each energy level and read out to memory as 16-bit words. The high rate LAD data are stored in two (address 24 and 25) 16-bit accumulators. If any one of the LAD accumulators (address 0-14) overflow, the time of occurrence is recorded in a (address 15) 16-bit accumulator and the remaining LAD accumulators are stopped.

Pulsar Mode

In the Pulsar Mode, the five accumulators (address 10-14) which were allotted to the high energy portion of the LAD spectrum during the normal mode are now assigned to recording the time of occurrence of each count from the large area detectors. The times of the first seven pulsar events are recorded with a precision of one millisecond. The accumulators are sampled and reset once each second by the on-board computer. Clock signals are gated into the five accumulators in parallel. The accumulators continue to count until stopped sequentially by the first seven events. A clock stability good to about 1 part in 5×10^{-7} is required in this measurement. All other data and sampling rates discussed in the normal mode remain the same for the Pulsar Mode. The data configuration and sampling rates are given in Table 2.2.

In-Flight Calibration

The in-flight calibration devices consist of calibration rods with radioactive sources that normally face away from the proportional counters. Upon command, the rod is rotated by a rotary solenoid, thereby positioning the sources facing the counters. After the calibrate command has been initiated, the solenoid drivers control the duration of the calibration cycle, thereby eliminating the need for two "Calibrate Off" commands that would otherwise be required.

Table 2.1: Configuration of Output Accumulators for Normal Mode

Output Accumulator Address	Contents of 16-Bit Output Accumulators	Sample Rate
0	LAD PH 0	1 per 256 sec.
1	LAD PH 1	1 per 256 sec.
2	LAD PH 2	1 per 256 sec.
3	LAD PH 3	1 per 256 sec.
4	LAD PH 4	1 per 256 sec.
5	LAD PH 5	1 per 256 sec.
6	LAD PH 6	1 per 256 sec.
7	LAD PH 7	1 per 256 sec.
8	LAD PH 8	1 per 256 sec.
9	LAD PH 9	1 per 256 sec.
10	LAD PH 10	1 per 256 sec.
11	LAD PH 11	1 per 256 sec.
12	LAD PH 12	1 per 256 sec.
13	LAD PH 13	1 per 256 sec.
14	LAD PH 14	1 per 256 sec.
15	Time of LAD Overflow	1 per 256 sec.
16	BD 1 PH 0 BD 2 PH 0	1 per 256 sec.
17	BD 1 PH 1 BD 2 PH 1	1 per 256 sec.
18	BD 1 PH 2 BD 2 PH 2	1 per 256 sec.
19	BD 1 PH 3 BD 2 PH 3	1 per 256 sec.
20	BD 1 PH 4 BD 2 PH 4	1 per 256 sec.
21	BD 1 PH 5 BD 2 PH 5	1 per 256 sec.
22	BD 1 PH 6 BD 2 PH 6	1 per 256 sec.
23	BD 1 PH 7 BD 2 PH 7	1 per 256 sec.
24	LAD 1	1 per 16 sec.
25	LAD 2	1 per 16 sec.

Table 2.2: Configuration of Output Accumulators During Pulsar Mode

Output Accumulator Address	Contents of 16-Bit Output Accumulators	Sample Rate
0	LAD PH 0	1 per 256 sec.
1	LAD PH 1	1 per 256 sec.
2	LAD PH 2	1 per 256 sec.
3	LAD PH 3	1 per 256 sec.
4	LAD PH 4	1 per 256 sec.
5	LAD PH 5	1 per 256 sec.
6	LAD PH 6	1 per 256 sec.
7	LAD PH 7	1 per 256 sec.
8	LAD PH 8	1 per 256 sec.
9	LAD PH 9	1 per 256 sec.
10	Time of 1st Pulsar Event	1 per sec.
11	Time of 2nd Pulsar Event	1 per sec.
12	Time of 3rd Pulsar Event	1 per sec.
13	Time of 4th Pulsar Event	1 per sec.
14	Time of 5th Pulsar Event	1 per sec.
15	Time of LAD Overflow	1 per 256 sec.
16	BD 1 PH 0 BD 2 PH 0	1 per 256 sec.
17	BD 1 PH 1 BD 2 PH 1	1 per 256 sec.
18	BD 1 PH 2 BD 2 PH 2	1 per 256 sec.
19	BD 1 PH 3 BD 2 PH 3	1 per 256 sec.
20	BD 1 PH 4 BD 2 PH 4	1 per 256 sec.
21	BD 1 PH 5 BD 2 PH 5	1 per 256 sec.
22	BD 1 PH 6 BD 2 PH 6	1 per 256 sec.
23	BD 1 PH 7 BD 2 PH 7	1 per 256 sec.
24	LAD 1	1 per 16 sec.
25	LAD 2	1 per 16 sec.

2.4 Experiment/Spacecraft Interfaces

The Experiment Interfaces directly with the following Spacecraft subsystems and the Ground Support Equipment.

- Structure
- Thermal Control
- On-Board Computer
- Power Supply

A summary of the principal requirements imposed on the spacecraft is given in Table 2.3.

Weight

A weight summary of the Experiment is given in Table 2.4. The estimated weight of the proposed package totals 7.03 kg. The maximum weight allotment of 8.0 kg. will be maintained to provide some growth contingency since the Experiment design is not yet frozen.

Alignment

The Experiment must maintain an alignment of 1 arc-minute about the spacecraft Z-Axis during orbit. However, misalignment as large as 5 arc-minutes caused by mechanical settling after launch and initial thermal stabilization can be tolerated provided this misalignment remains fixed. In this case the offset between the experiment and the star sensor would have to be calibrated as soon as possible after observations begin by scanning across a strong source whose position is known. Alignment requirements for the Y- and X-Axes which are to be supplied will not be as stringent as the Z-Axis requirement.

Alignment will be carried out by using a reference mirror mounted on the package or some similar technique.

Thermal

The Experiment Thermal Environment shall be $0^{\circ}C$ to $40^{\circ}C$ as required by the proportional counters.

Table 2. 3

Summary of Principal Experiment Requirements

1.	Size	34 cm (Z) wide x 24 cm (X) high x 12 cm (Y) deep
2.	Viewing Aperture:	31 cm x 12 cm (max.)
3.	Weight:	8 kg. (max.)
4.	Humidity: (see page 7-1)	55% relative humidity (max.)
5.	Alignment:	$\pm$ 1 arc-minute (Z-Axis) TBS (Y-Axis) TBS (X-Axis)
6.	Thermal:	$0^{\circ}C$ to $40^{\circ}C$ (Proportional Counters)
7.	On-Board Memory:	Normal Mode - 3.5 bps. * Pulsar Mode - 115 bps. *
8.	Spacecraft Clock Signal:	524288 Hz.
9.	Spacecraft Clock Stability:	1 part in 5×10^{7}
10.	Telemetry (Exp. Hskg.):	8 Analog Signals and 10 Status (Logic) signals sampled at least once per 256 seconds.
11.	Commands:	12
12.	Power:	3 Watts Average
13.	Connectors	3
14.	Grounding:	Separate power, shield, and chassis grounds
15.	Pointing:	$\pm$ 1 arc-minute*
16.	Gating Pulse:	To gate clock for 16 bit readout
17.	Address:	5 bit address

*Memory and Pointing Requirements depend on the specific type of observation as given in the observing plan (Appendix).

Table 2.4

Hard X-Ray Experiment Weight Summary

Collimator	2.34 Kilograms
Large Area Detector and Preamplifiers	0.76 "
Bragg Crystals	0.66 "
Bragg Detector and Preamplifiers	0.45 "
Housing	0.56 "
Electronics Subassembly	0.57 "
Low Voltage Power Supply	0.30 "
High Voltage Power Supplies (2)	0.81 "
Brackets, Connectors, Clamps, Etc.	0.59 "
Contingency	0.96 "
	8.00 Kilograms

Preliminary evaluations of the operational environment within the ANS Spacecraft indicate that the Experiment can operate satisfactorily when the only means of heat transfer is by radiation.

On-Board Computer

The Experiment will interface with the on-board computer. The contents of the experiment accumulators are twenty-six 16-bit accumulators which will be transferred serially to the computer on computer command through a 16-bit standard computer input interface. The data shall be read out according to addresses supplied by the computer. A 5-bit address word is required. The address will interface with the experiment through a standard computer output interface. The standard computer input and output interfaces are defined in Section 3. 3. 2. 5 and 3. 3. 2. 6, ANS System Specification, respectively.

A 524288 Hz Clock Signal and a Transfer Pulse are also required from the computer to control these interfaces.

The data contained in the accumulators and the desired sampling rates were shown in Tables 2. 1 and 2. 2 for the Normal Mode and Pulsar Mode, respectively. The bit rates are 3. 5 bps. for the Normal Mode and 83.2 bps. for the Pulsar Mode. It is assumed that alternate 12-hour periods are available for x-ray and U. V. observation and that during the x-ray observing period, one-half of the available data storage in the on-board computer is assigned to the Hard X-Ray Experiment. Thus, 160, 000 bits of storage are available during alternate 12-hour periods. While there is no storage problem concerning the Normal Mode, some methods of conserving bits must be explored for the Pulsar Mode.

The observing plan (scientific section) lists variations of the above bit rates and total storage requirements as controlled by the on-board computer when viewing specific objects.

Stability of the Spacecraft Clock

The data from up to twelve hours of observing time in the pulsar mode will be combined to a precision of one millisecond. This will require an on-board clock whose frequency is stable to about one part in 5×10^7 or better.

Power, Command and Telemetry Housekeeping

The power, command and telemetry housekeeping requirements are given in Table 2.5.

Connectors

The electrical interface connectors mounted on the package will consist of three Deutsch receptacle-type subminiature connectors. These connectors interface with power, GSE, and the computer, Telemetry (housekeeping) and command decoder units.

This type of connector, Deutsch RE64 series was recommended for use by the Netherlands Consortium.

Grounding

The experiment will use a three-wire grounding system in which the chassis signal and power ground are kept separate and made available at the interface connector.

Table 2. 5

Power, Command and Telemetry Housekeeping

	POWER		
	+20V Requirement		
	+6. 75V		0. 45 watts (average)
	-6. 75V		0. 45
	LVPS losses at 70% eff.		0. 39
	HVPS (one operating at a time)		0. 70
TOTAL	+20V Requirement		1. 99
TOTAL	+5V Requirement		1. 00
		TOTAL	2. 99 watts (average)

COMMANDS			
Experiment	On-Off		2 Commands
High Voltage #1	On-Off		2 Commands
High Voltage #2	On-Off		2 Commands
Pulsar Mode	On-Off		2 Commands
Calibration	LAD-BD		2 Commands
PSD	On-Off		2 Commands
		TOTAL	12 Commands

TELEMETRY (HOUSEKEEPING)		
Analog Voltage		
Monitors:	4	+6. 75 Volts
		-6. 75 Volts
		HVPS #1
		HVPS #2
Temperature Monitors:	4	
Status Monitors:	10	
TOTAL	18	

3.0 MECHANICAL DESIGN

3.1 Design Configuration of AS&E Experiment

The design of AS&E's experiment portion of the Astronomical Netherlands Satellite consists of a single package mounted to the spacecraft, as shown in Figure 3-1, which houses all elements of the experiment, including the electronics.

<u>Overall Configuration</u>

(1) Maximum Envelope: 34 cm x 12 cm x 24 cm

(2) Maximum Weight: 8 Kg

<u>Large Area Detector (LAD)</u> - 2 Req'd

(1) To have a collimated field-of-view of 10' x 3°, without sidebands.

(2) Each detector to have an effective area of 35 cm^2.

(3) Each detector to have a 3-mil Be window and contain a maximum one-atmosphere gas-pressure fill.

(4) The 10' field-of-view of each collimator will be offset 5' with respect to the other.

<u>Bragg Crystal Spectrometer</u> - 2 Req'd

(1) To have a collimated field-of-view of 3°.

(2) Each detector to have an effective area of 20 cm^2.

(3) Each detector to have a 1-mil Be window with a maximum two-atmosphere gas-pressure fill.

(4) Crystal orientation angles to be between 20° and 70°.

(5) Optical centerline of Bragg Crystal Collimator to be aligned within 1' of LAD Collimator optical centerline.

3.2 Structural Design

Due to design weight and volume limitations, where possible all structural elements will be fabricated of sheet metal with an

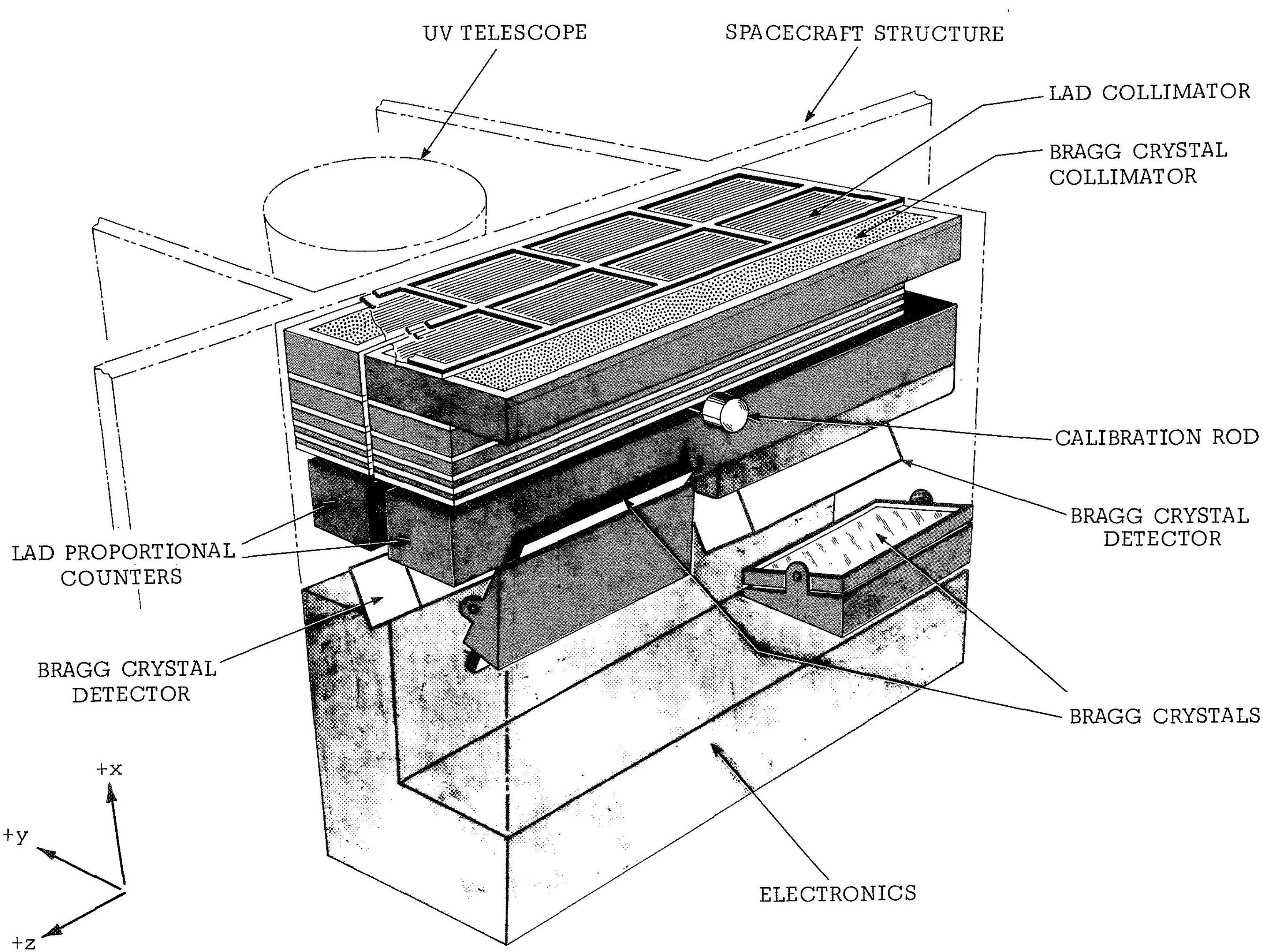


Figure 3-1. Configuration of ANS Hard-X-Ray Experiment

attempt made to use common frames to support multiple elements, (e. g., the two LAD Collimators will be treated as a combined subassembly to which their detectors - the Bragg Crystal Collimators and the crystal mounting surfaces - can be attached). The entire subassembly can be installed in the experiment housing which will be made of sheet metal. More importantly, however, this design approach will enable optical alignment in the laboratory of all of the collimators as an assembly, thus eliminating any buildup of tolerances which would occur if a mechanical stack up were attempted.

The detector design does not appear to present any major problems from a functional point of view since they are similar to other proportional counters which have been successfully flown in space applications. The only problem areas relate to achieve the desired effective area within the allocated Experiment viewing limitations.

Since the optical elements will have been aligned prior to installation in the instrument package (possibly with a mirror surface supplied which will enable external reference to the optical centerline), the package itself will be mounted to the spacecraft with provisions for alignment with respect to the U. V. telescope optical axis. Figure 3-2 shows mechanical detail for the Experiment.

3. 3 Structural Analysis

The three environmental phases that the experiment must endure are as follows:

Ground-Handling Phase

The experiment structure must have the ability to endure ground-handling shock and vibration loadings without suffering permanent deformation or loss of alignment. To a large extent the Experiment will be protected against this environment by proper packaging

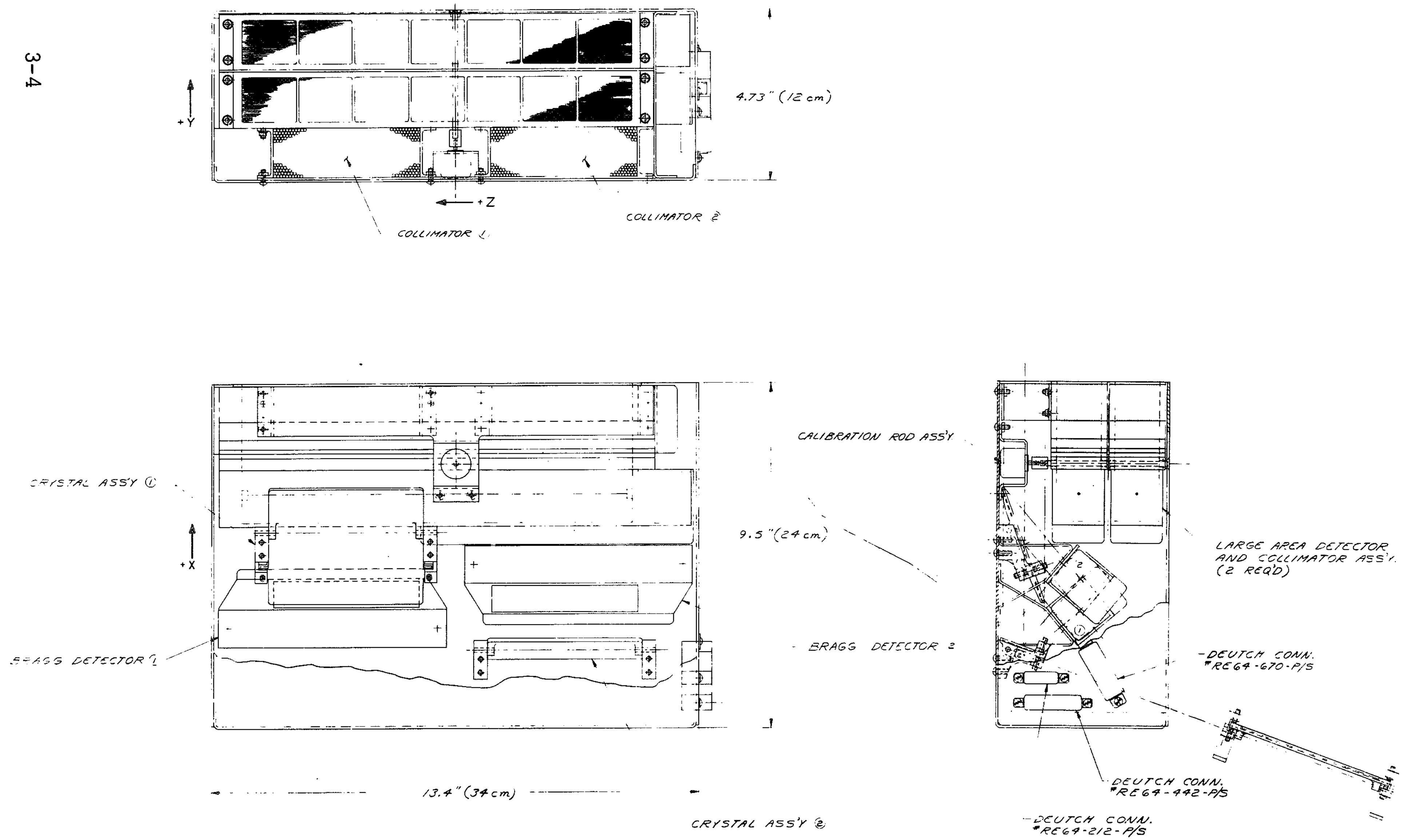
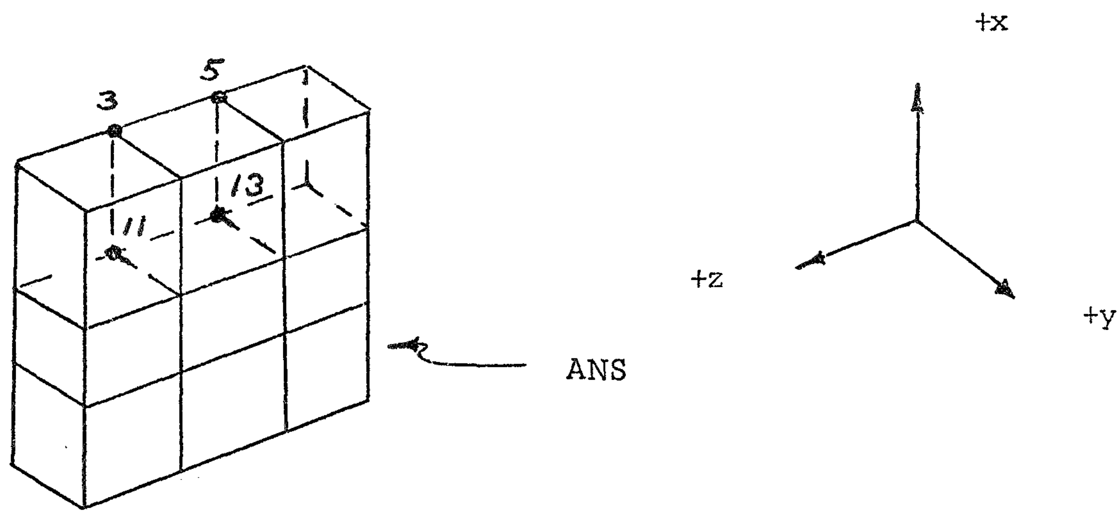


Figure 3-2. Mechanical Detail, ANS Hard X-Ray Experiment

during storage and shipment. Proper care taken during bench-handling of the Experiment will also be required.

Ascent Phase

The Experiment must have the ability to endure this phase of its life without suffering permanent deformation or loss of alignment. The dynamic loadings pertinent to the Experiment during its ascent phase is shown in Table 3.1. The experiment location relative to the ANS is shown below in Figure 3-3.



Nodes 3,5,11,13 define the experiment location to the ANS.*

Figure 3-3. Hard X-Ray Experiment Location in ANS

---

*Reference: Figures 2.8-5, 2.8-6, 2.8-7, 2.8-8 of ANS Design Study dated November 1969.

Table 3.1

Axis	Frequency (CPS)	Scout S ine Input**	Experiment Response @ f_1*
X	10-18 18-44 44-65 65-2000	1.0 g 0.06" D. A. 6.0 g 4.5 g	22 g @ 192 cps
Y	10-20 20-28 28-2000	0.75 g 0.038" D. A. 1.5 g	27 g @ 38 cps 9 g @ 125 cps
Z	10-20 20-28 28-2000	0.75 g 0.038" D. A. 1.5 g	27 @ 38 cps 9 @ 125 cps

The random environment (Scout Input) appears to have no great impact on the design loading based on the relationship between the sinusoidal equivalent of random vibration for the ANS system natural frequencies stated in Volume IV,

$$g_{rms} \ (1\sigma) = \sqrt{f_n \ \frac{\pi}{2} \ Q \ (PSD)}$$

page 2.31 of ANS Design Study dated Nov. 1969

Orbital Phase

The structural problems associated with the orbital phase are due mainly to temperature gradients across the experiment. The effect of temperature grandients within the experiment is to induce distortion and possibly misalignment of critically aligned components. As yet, these gradients are undefined. Following their definition, a comprehensive study of the effects of thermal gradients on the alignment of the experiment will be undertaken.

---

*Reference: Figures 2.8-5, 2.8-6, 2.8-7, 2.8-8 of ANS Design Study dated Nov. 1969

**Qualification Level

3.4 Preliminary Analysis of Collimator Wires

The preliminary parameter study was made in order to define relationships between tensile stress, free span length, and natural frequency for candidate wire materials. The study was made on the basis of the formula:

$$f_n = \frac{n}{2\ell} \sqrt{\frac{T}{\rho}}$$

from which can be derived:

$$\sigma_t = \frac{T}{A} = \frac{\rho}{A} \left(\frac{2f_n \ell}{n} \right)^2$$

(tensile stress)

Where:

f_n = natural frequency, cps

n = 1, 2, 3 . . . . (mode shape)

ℓ = free span length

A = cross sectional area of wire

ρ = wire mass density per unit length

T = wire tension

The results of the study are shown in Tables 3.2(a) and (b) for natural frequencies of 2000 cps and 5 cps, respectively.

The study indicates that it is desirable to have a low tensile stress, low natural frequency design. This may be the case; however, the effect of wire-flexing at its end supports is also being considered in the high amplitude, low natural frequency region. Some development vibration testing on typical collimator samples will be conducted before a final design is approved.

3.5 ANS Thermal Design

In order to evaluate the thermal environment of the ANS experiment, the following preliminary study was performed.

Table 3. 2 (a)

Wire Parameter Study ~ $f_n \geq 2000$ cps

Wire	σ_t ~ psi x 10^{-6} (tensile stress)				
Material	l = 11"	l = 5.5"	l = 4."	l = 2"	l = 1"
Tugsten	3.5	.88	.46	.12	.03
St. Stl.	1.5	.36	.19	.05	.01
Copper	1.6	.40	.21	.05	.01

Table 3. 2 (b)

Wire Parameter Study ~ $f_n \leq 5$ cps

Wire	σ_t ~ psi (tensile stress)		
Material	l = 11"	l = 5.5	
Tungsten	2200	550	
St. Stl.	945	236	
Copper	1000	250	

Radiant interchange between sides of the package and internal spacecraft surfaces for dissipating heat are investigated in the following approach.

Available for radiating surface area are 2 surfaces 4" x 9", 2 surfaces 9" x 13", and one surface 4" x 13", or a total of 2.485 Ft.^{2}.

Complete radiative coupling between these surfaces and the spacecraft surfaces, i.e. emissivity (ϵ) $\equiv$ 1.0 is assumed.

Then, the equivalent thermal resistance, R, is derived from the relation,

$$R = \frac{1}{4\sigma\epsilon AT^3} = \frac{1}{4 \times .173 \times 10^{-8} \times 1 \times 2.485 \times 1.5 \times 10^{+8}} = .397\ {}^{\circ}F/BTU/HR.$$

where σ = Stefan Boltzman Constant = 0.173×10^{-8} BTU/Ft^2 Hr $({}^{\circ}R)^4$

Temperature is assumed to be +70°F. Then, using a very conservative heat load of 5.0 watts (17.06 BTU/HR), $\Delta T = qR = 17.06 \times 0.397 = \underline{\underline{6.78}}\,{}^{\circ}F$.

While radiant heat interchange has been shown adequate for favorable thermal environment of the AS&E experiment, some conductive interchange will necessarily take place, which the following assesses.

The large electronics package mounting surface area cannot be fully utilized since a requirement for mechanical movement of the instrument package for optical alignment exists. Therefore, a smaller contact area must be assumed, with a conductance efficiency of 40% in the joint. A feasible maximum contact area is a square 1.5 inches on a side or 15.75×10^{-3} ft.^{2}. Assuming a thermal path length of 4 inches and aluminum as the material for this conductor Al 6061, $\left(K = 100 \dfrac{BTU}{\frac{Ft^2\ {}^{\circ}F\ Hr}{Ft}} \right)$

The thermal resistance is then:

$$R = \frac{1}{kA} = \frac{0.3333}{6.3 \times 10^{-3} \times 10^{-2}} = 0.528\ ^{\circ}F/BTU/HR.$$

From the relation $qR = \Delta T$,

$$\Delta T = 17.06 \times 0.528 = 9^{\circ}F = 5^{\circ}C.$$

The electronics package temp. is then $T_{sink} + \Delta T = T_{elect.}$, $T_{sink} \approx +9^{\circ}C$. (from preliminary data from the ANS Design Study dated November 1969), $T_{elect.} = 9 + 5 = 14^{\circ}C$.

It would seem that either of the above analyses shows favorable thermal environment for the AS&E Experiment. Note that each analysis assumes complete independence of the other.

3.6 Collimator

The primary thermal problem in the collimator relates to temperature differential from the top grid to the bottom grid plane. Since the field-of-view of the collimator is determined by the consistency of spacing of the wires across the short (1.5 inch) dimension (normal to the span of the wire), the following assesses what temperature differential from the top to the bottom of the collimator is acceptable.

The specified field-of-view of each LAD Collimator is 10' ± 1', which, converted to linear dimension over the two-inch depth of the collimator, is approximately 0.0005". Assume an aluminum frame with a coefficient of thermal expansion, α, = 13×10^{-6} in/in/$^{\circ}$F.

Then $\Delta \ell = \ell \alpha \Delta T$

$$\Delta T = \frac{0.005''}{(1.5'')\,(13 \times 10^{-6} \text{in/in/}^{\circ}\text{F})}$$

$$= 25.6^{\circ}\text{F}$$

Thus, the acceptable temperature variation is 25.6°F.

Since the temperature departure from the nominal has been calculated to be 6.78°F, it appears that collimator distortion by temperature variation is not a problem.

3.7 Analytical Design

Thermal Analytical Models

Analytical thermal models will be constructed and utilized for parametric and optimization studies of thermal system design, and to predict system performance. The following models will be formulated and used:

(a) A gross model for use in studying overall system design and performance.

(b) Detailed models of each of the following:

- Collimator
- Bragg Crystal System
- Electronics Packaging System (if required).

Analytical Programs

Standard, well-known heat-transfer programs suitable for IBM 360 machines (or equivalent) will be used. Use of other than AS&E computer capability will be limited to those cases wherein the necessity clearly exceeds the AS&E capability. AS&E has access to and will make use of a wide variety of programs such as CINDA, TOSS, CONFAC II, etc.

Design Problems

The primary design problem is associated with the construction of the Large Area Detector collimators. A design which will achieve the scientific requirements can be described as one consisting of six planes of grids made up of 6-mil wires with 6-mil spacing, the six planes occupying a depth of two inches, the plane spacing being 2", 1", 0.5", 0.25", 0.125", and 0.125", respectively.

Two possible construction techniques are currently under consideration. The first would be to use a wire-wound approach, using 6-mil tungsten or palladium wires as shown in Figure 3-4. Since the wires are stretched parallel to the long dimension supporting cross-members would be provided to reduce the free length of wire and to increase the natural frequency of the system.

An alternate approach would be to use a flat plate which would be electro-etched to provide the desired grid pattern as shown in Figure 3-5.

With either design, the assembly would consist of a series of appropriate spacers which would provide a sandwich type of collimator as shown in Figure 3-6. The advantage of this type of assembly lies in the fact that each collimator grid can be individually aligned with the preceding grid and then be locked into position, assuring the desired field-of-view through the total assembly and a minimum weight.

The 3° field-of-view will be acheived by the use of a tube-type collimator sandwiched between the first two planes of the grid collimator.

The tube collimator will be assembled separately and held in place

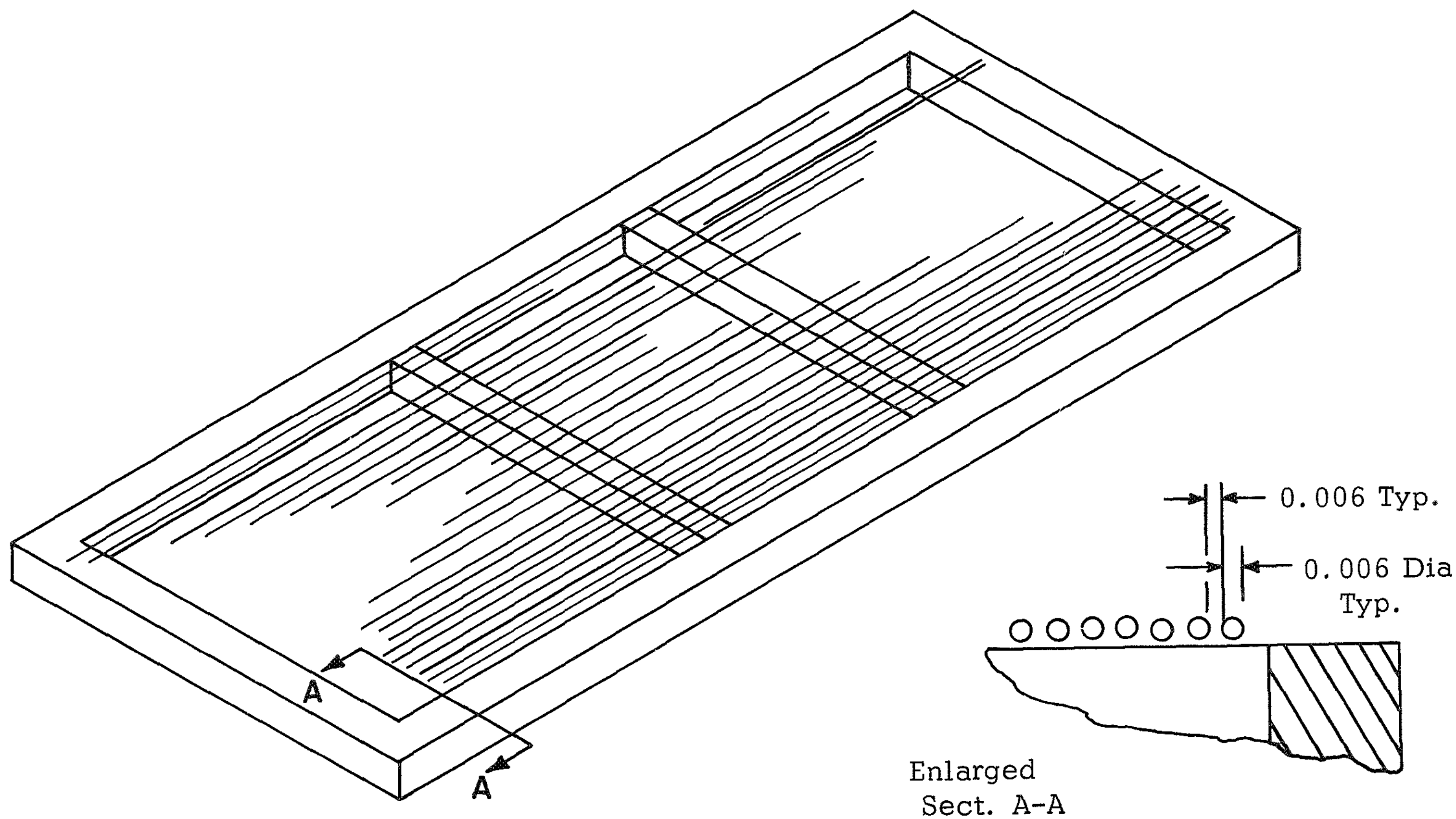


Figure 3-4. LAD Collimator Wire-Wound 6-mil Tungsten or Palladium Construction Technique

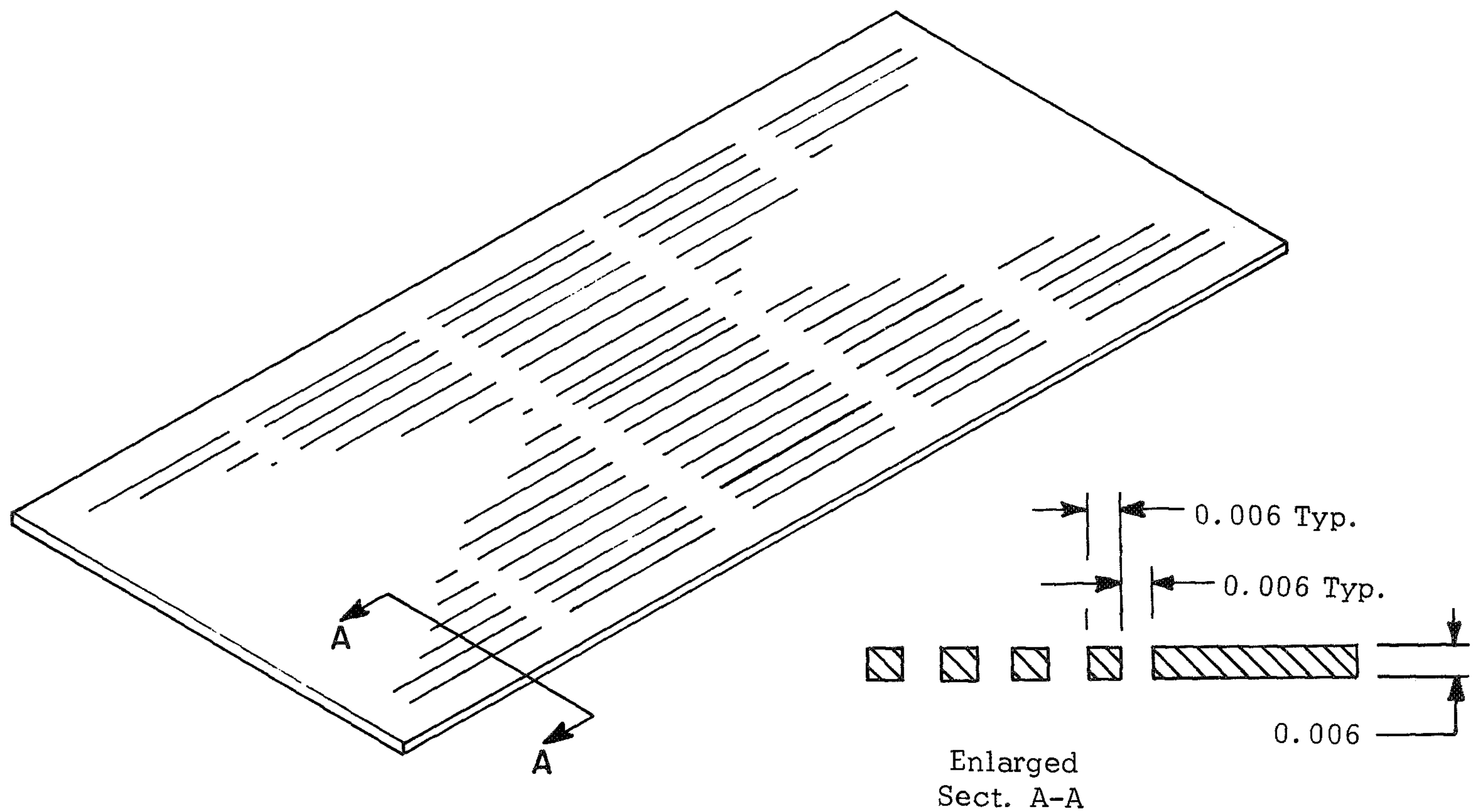


Figure 3-5. Alternate LAD Collimator Electro-Etched, Flat-Plane Construction Technique

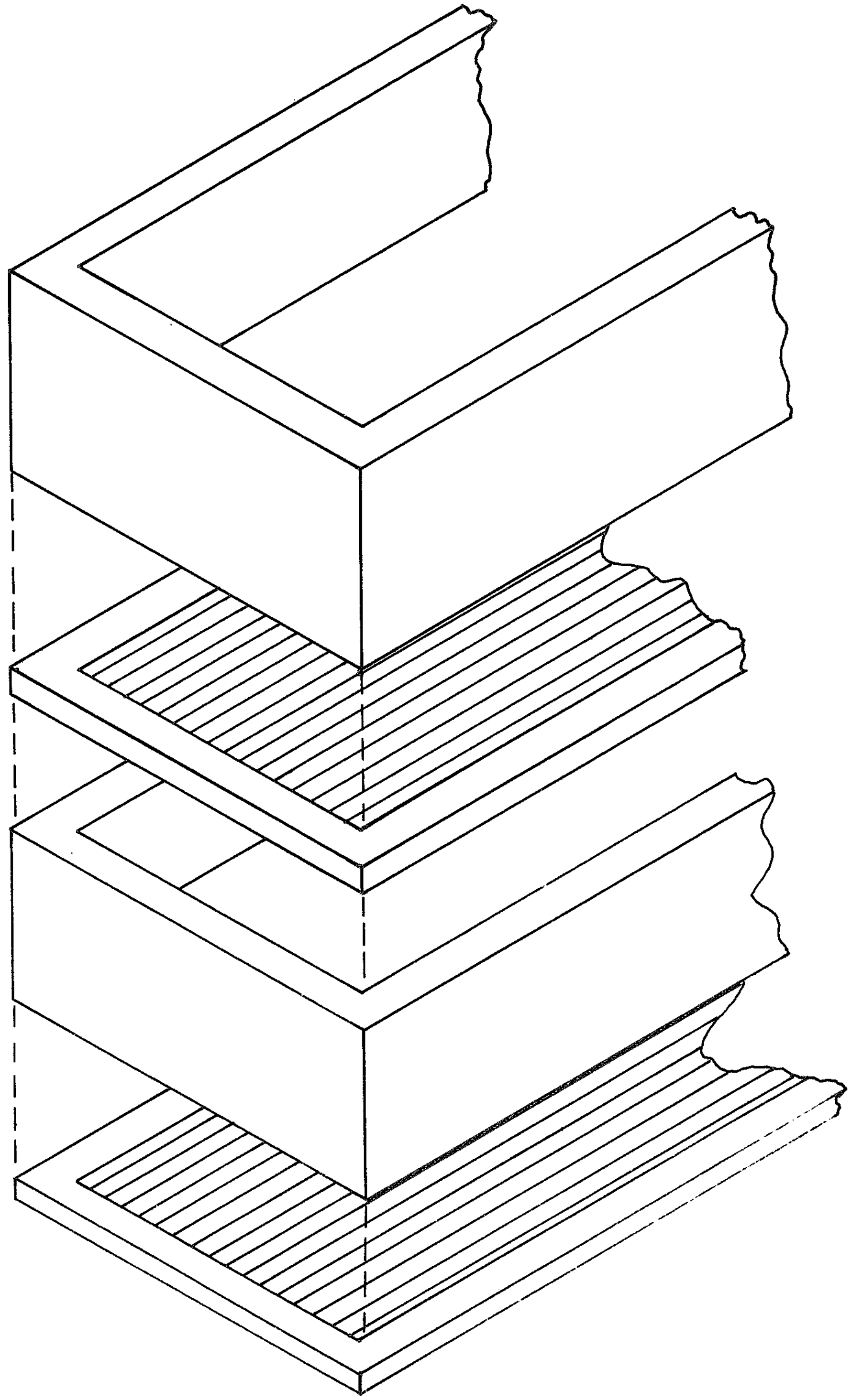


Figure 3-6. LAD Collimator, Appropriate Spacers Providing Sandwich-Type Construction Arrangement

between the grids by the spacers which make up the grid assembly.

In the case of the Bragg Crystal Collimator, the same construction could be used except, in this case, the collimator would be attached to the outer surface of the large area collimator as shown in Figure 3-7.

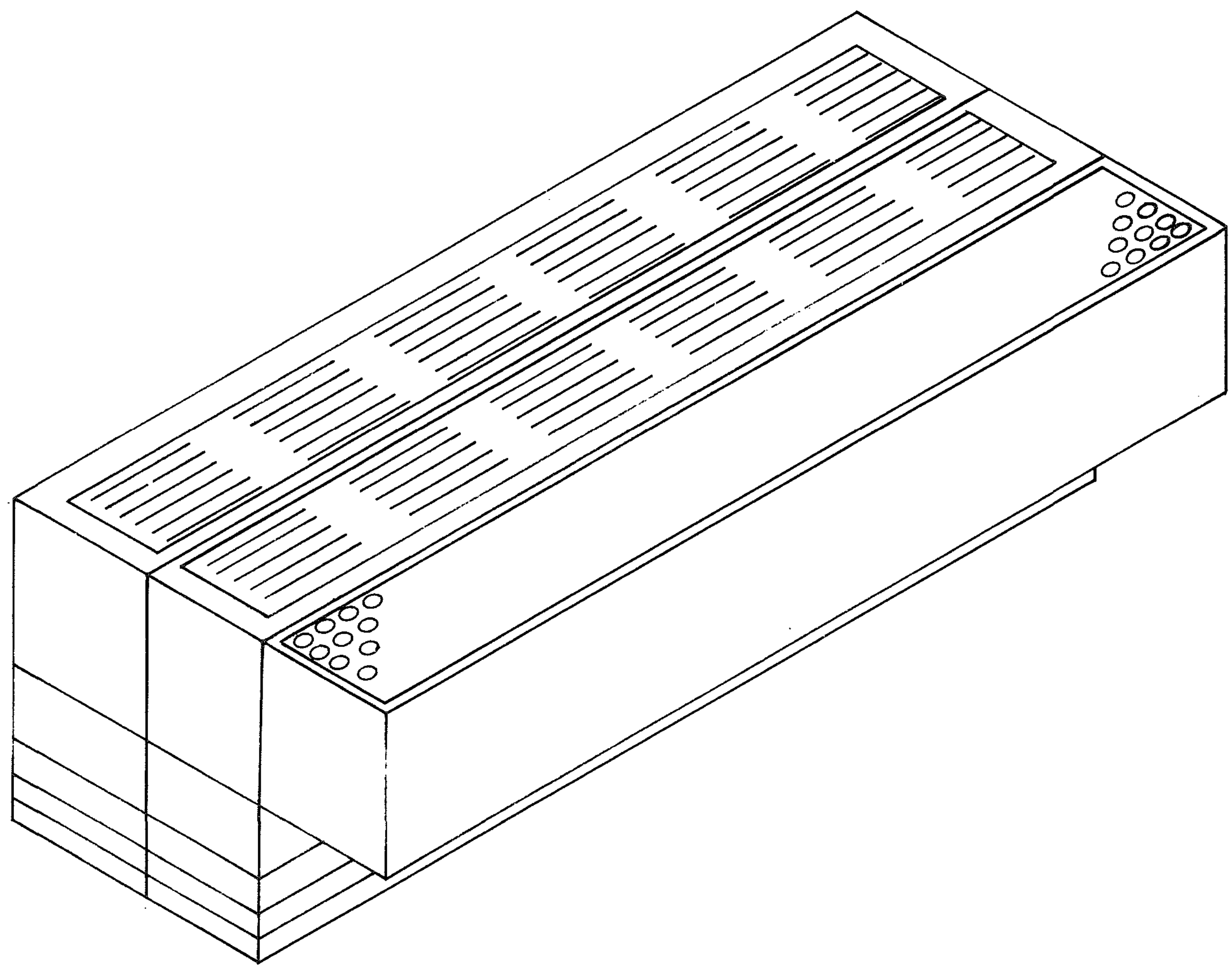


Figure 3-7. Bragg Crystal Collimator Construction Arrangement

4.0 ELECTRONICS DESIGN

4.1 Introduction

This section describes the Experiment electronics system and its components, where pertinent. The Experiment shown in block diagram form in Figure 4-1 consists of five electronic subsystems which are described below. The subsystems are:

(1) Detector Electronics

(2) Pulse Analysis Electronics

(3) Data Processing and Buffer Storage

(4) Power and Command Distribution

(5) Calibration

4.2 Detector Electronics

The detector electronics is that hardware which is co-located and interfaces with the proportional counters. As shown in the block diagram (Figure 4-2), this hardware is the high voltage supplies and the preamplifiers as well as the high-voltage biasing networks.

The scientific requirements permit all four proportional counters to be operated at the same voltage. Thus, there is sufficient room to provide a fully redundant high voltage supply such as shown in Figure 4-2, where each half may be commanded on or off, independent of the other half. Dissipative preregulators provide buffering between the Jensen chopper and the regulated spacecraft voltage.

The preamplifiers will be designed with low noise and gain stability as the prime considerations. To achieve low noise, the preamplifier front end will be designed around junction field-effect transistors, such as the Texas Instrument SFC2674, which exhibit very low noise and high transconductance. High open-loop gain and negative feedback will be utilized in the design to obtain the require stability. A low noise preamplifier design, consisting of a charge-sensitive front end and a voltage amplifying output stage, is shown in Figure 4-3. This circuit was used by AS&E in a similar application.

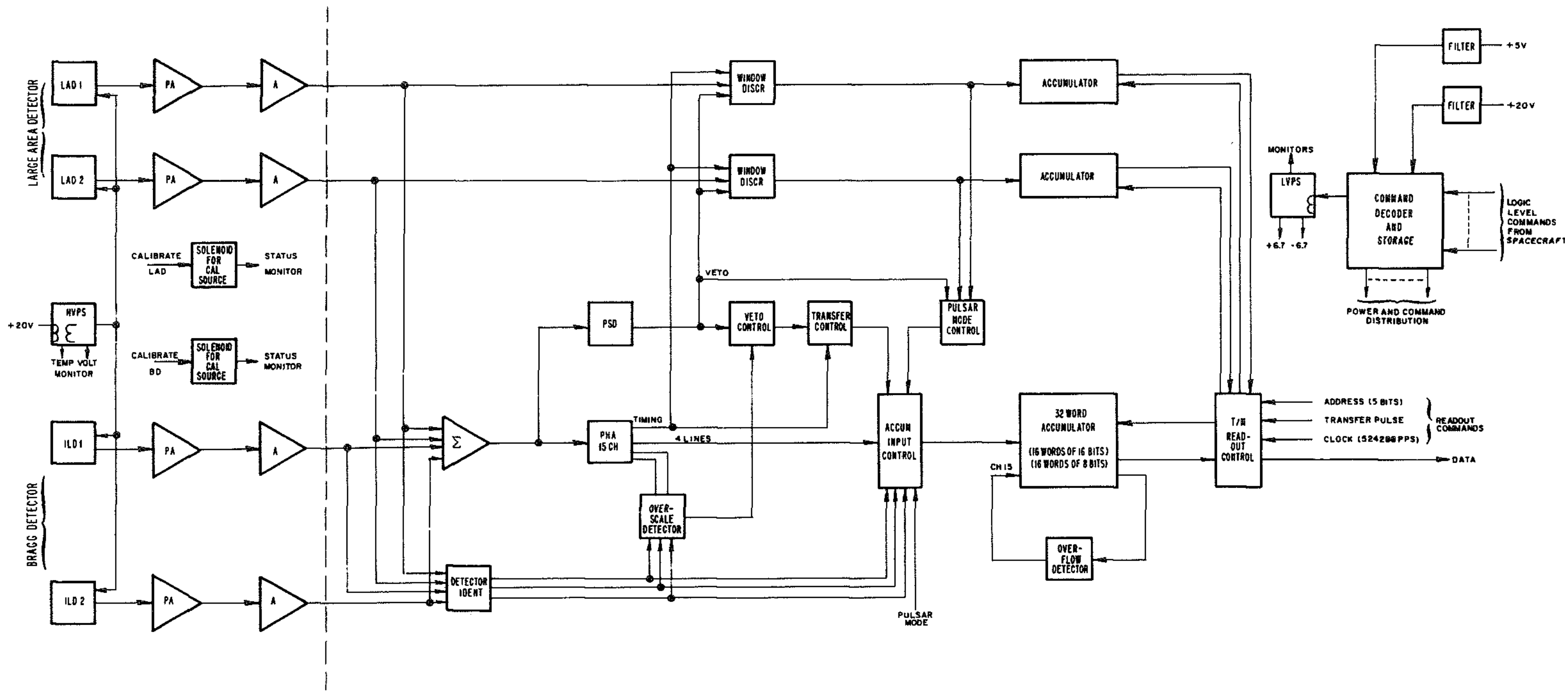


Figure 4-1. Electronics Block Diagram for ANS Hard-X-Ray Experiment

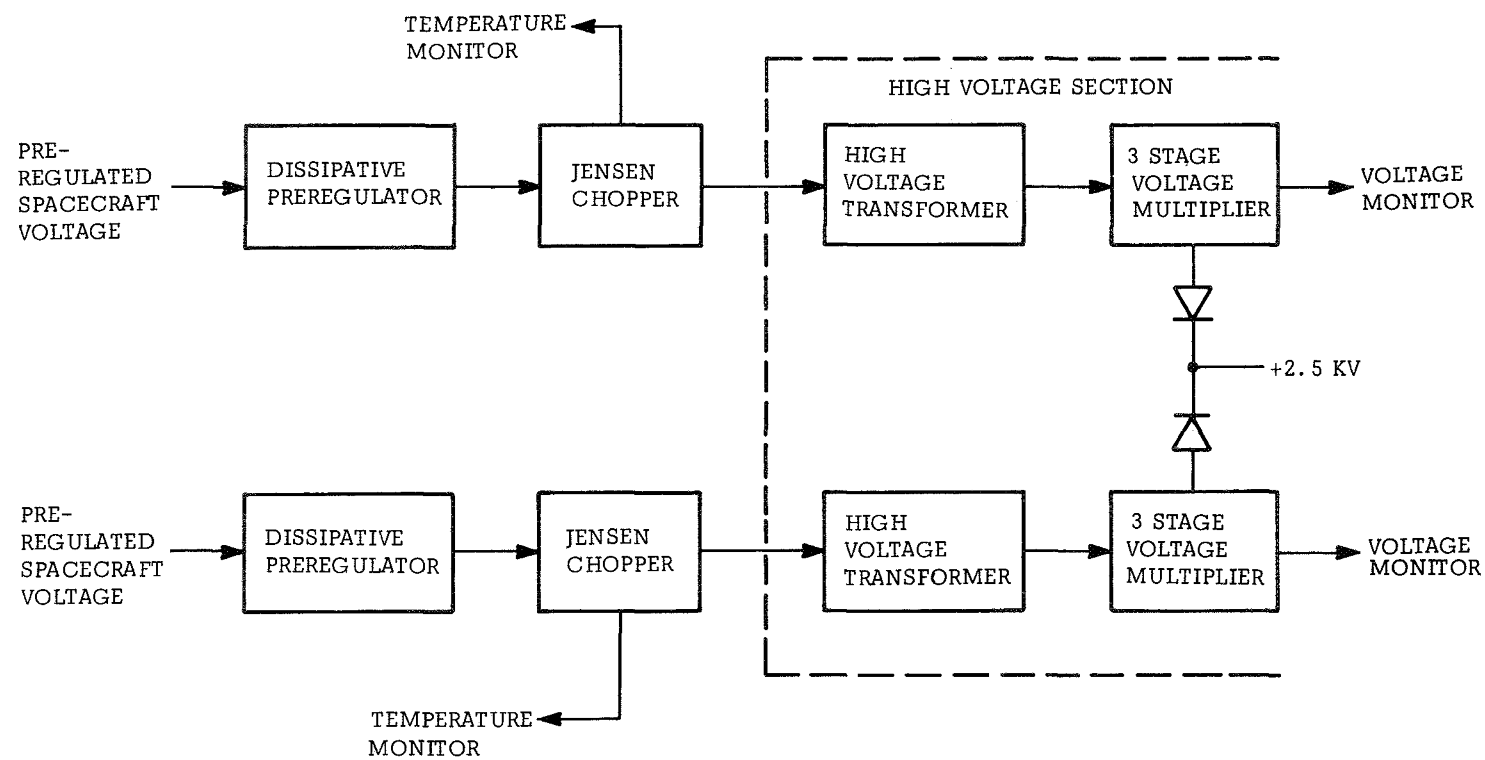


Figure 4-2. High Voltage Supplies

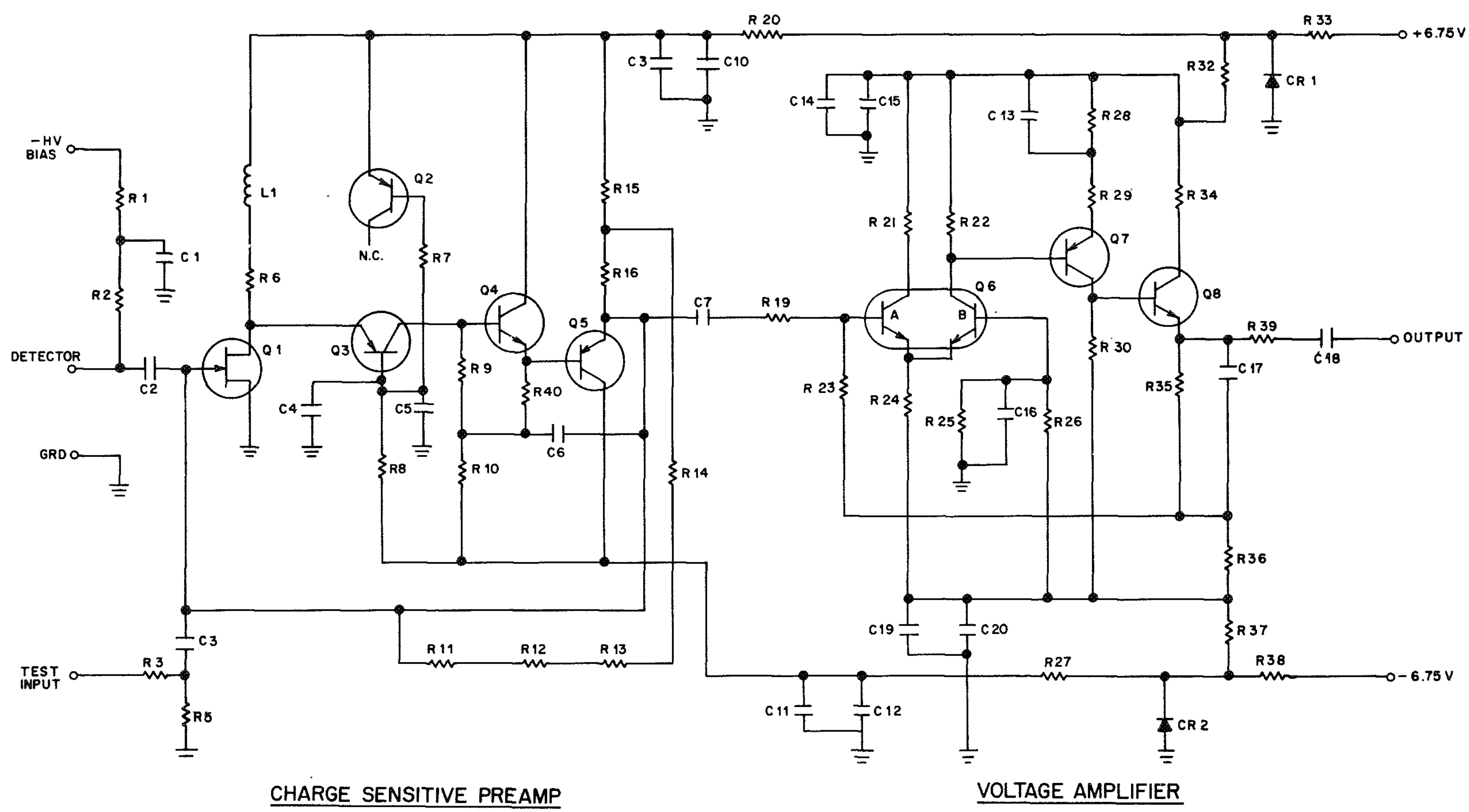


Figure 4-3. Preamplifier

4.3 Pulse Analysis Electronics

Pulse data from both the Large Area Detector (LAD) and the Bragg Detector (BD) are analyzed on the basis of pulse shape and amplitude. A veto signal is generated if the rise-time of the pulse exceeds the limits established for x-rays. If no veto signal is generated, the pulse amplitude is used to address the appropriate scalar.

The electronics required to perform these functions are a pulse-shape discriminator and an "N"-channel pulse-height analyzer (PHA), where N is both 1 and 15 for the Large Area Detector and 8 for the Bragg Detector. Because of the normally low count rate, in the order of 1600 counts/second, it is possible to permit <u>one</u> 15-channel PHA to be shared by all detectors, thereby eliminating the need for a separate 8-channel PHA. The one-channel PHA for the LAD provides a high telemetry readout capability during periods of high intensity radiation and, therefore, cannot be combined with the 15-channel analyzer.

The outputs of the preamplifiers from the two LAD counters are, therefore, routed to a common summing amplifier, a detector identification circuit and separate window discriminators. At the same time, the Bragg Detector preamplifier outputs are routed to the same summing amplifier and detector identification circuit.

The summing amplifier combines the signals from the four detectors to a single pulse-shape discriminator (PSD) and a single multi-channel PHA. Simultaneously, the detector identification circuit records the source of the signal and informs the PHA whether it is to perform an 8- or 15-channel height analysis. The PHA circuit will be a height to time converter which has the advantages of low power and volume requirements. The detector identification circuit consists of four threshold detectors and associated storage and resetting functions.

The PSD requires further investigation. The problem is to achieve and accurate rise-time measurement over a wide range of energies using xenon-filled counters. Zero-crossing techniques have been used with success in previous instruments that utilized zrgon-filled counters and covered an energy range up to 20 KeV.

The outputs of the PSD and the PHA overscale detector control the veto gate which either permits or prohibits passage of the data to the accumulators. In addition, the PSD output resets the window discriminators. of the high-rate LAD accumulators if an undesired pulse has been detected.

4.4 Data Processing and Buffer Storage

The basic function of this subsystem is to accumulate and store the analyzed data. Hence, it consists of an Input Control (for routing), a 32-word Accumulator and a Telemetry Readout Control.

The Input Control selects, on the basis of detector origin and pulse-height analysis, which of 31 accumulators is to receive data. Fifteen of these are 16-bit accumulators for LAD data, 8 are 8-bit accumulators for one Bragg Detector, and 8 are 8-bit accumulators for the second Bragg Detector. In the interest of standardizing the telemetry format, the sixteen 8-bit accumulators are doubled-up and read out as eight 16-bit words. In addition, there are three 16-bit accumulators which bypass the Input Control; two of these are dedicated to the LAD detectors for high-rate operation, while the third, Accumulator Word 15, indicates the time at which the first normal rate accumulator overflowed.

Readout of the accumulators are accomplished via spacecraft control. The spacecraft presents the coded address of the desired accumulator and a transfer pulse to the instrument Readout Control. Upon receipt of the transfer pulse, the accumulator contents are strobed into a buffer register whose contents are then readout to the spacecraft in

CONFIGURATION OF DATA ACCUMULATORS FOR ON-BOARD COMPUTER

NORMAL MODE

Address	Contents of 16-Bit Address	T/M Readout
0	LAD P.H.0	1 per 256 sec
1	LAD P.H.1	"
2	LAD P.H.2	"
3	LAD P.H.3	"
4	LAD P.H.4	"
5	LAD P.H.5	"
6	LAD P.H.6	"
7	LAD P.H.7	"
8	LAD P.H.8	"
9	LAD P.H.9	"
10	LAD P.H.10	"
11	LAD P.H.11	"
12	LAD P.H.12	"
13	LAD P.H.13	"
14	LAD P.H.14	"
15	TIME OF LAD OVERFLOW	"
16	BD1 P.H.0 BD2 P.H.0	"
17	BD1 P.H.1 BD2 P.H.1	"
18	BD1 P.H.2 BD2 P.H.2	"
19	BD1 P.H.3 BD2 P.H.3	"
20	BD1 P.H.4 BD2 P.H.4	"
21	BD1 P.H.5 BD2 P.H.5	"
22	BD1 P.H.6 BD2 P.H.6	"
23	BD1 P.H.7 BD2 P.H.7	"
24	LAD 1 Accumulator	1 per 16 sec
25	LAD 2 Accumulator	"
	TOTAL	3.5 BPS

PULSAR MODE

Address	Contents of 16-Bit Address	T/M Readout
0	LAD P.H.0	1 per 256 sec
1	LAD P.H.1	"
2	LAD P.H.2	"
3	LAD P.H.3	"
4	LAD P.H.4	"
5	LAD P.H.5	"
6	LAD P.H.6	"
7	LAD P.H.7	"
8	Time of 1st. Pulsar Event	1 per sec
9	" 2nd "	"
10	" 3rd "	"
11	" 4th "	"
12	" 5th "	"
13	" 6th "	"
14	" 7th "	"
15	TIME OF LAD OVERFLOW	1 per 256 sec
16	BD1 P.H.0 BD2 P.H.0	"
17	BD1 P.H.1 BD2 P.H.1	"
18	BD1 P.H.2 BD2 P.H.2	"
19	BD1 P.H.3 BD2 P.H.3	"
20	BD1 P.H.4 BD2 P.H.4	"
21	BD1 P.H.5 BD2 P.H.5	"
22	BD1 P.H.6 BD2 P.H.6	"
23	BD1 P.H.7 BD2 P.H.7	"
24	LAD 1 Accumulator	1 per 16 sec
25	LAD 2 Accumulator	"
	TOTAL	115.0625 BPS

LEGEND: LAD: Large Area Detector
BD: Bragg Detector

Figure 4-4 ANS Hard X-Ray Experiment Telemetry Format for Data Readout

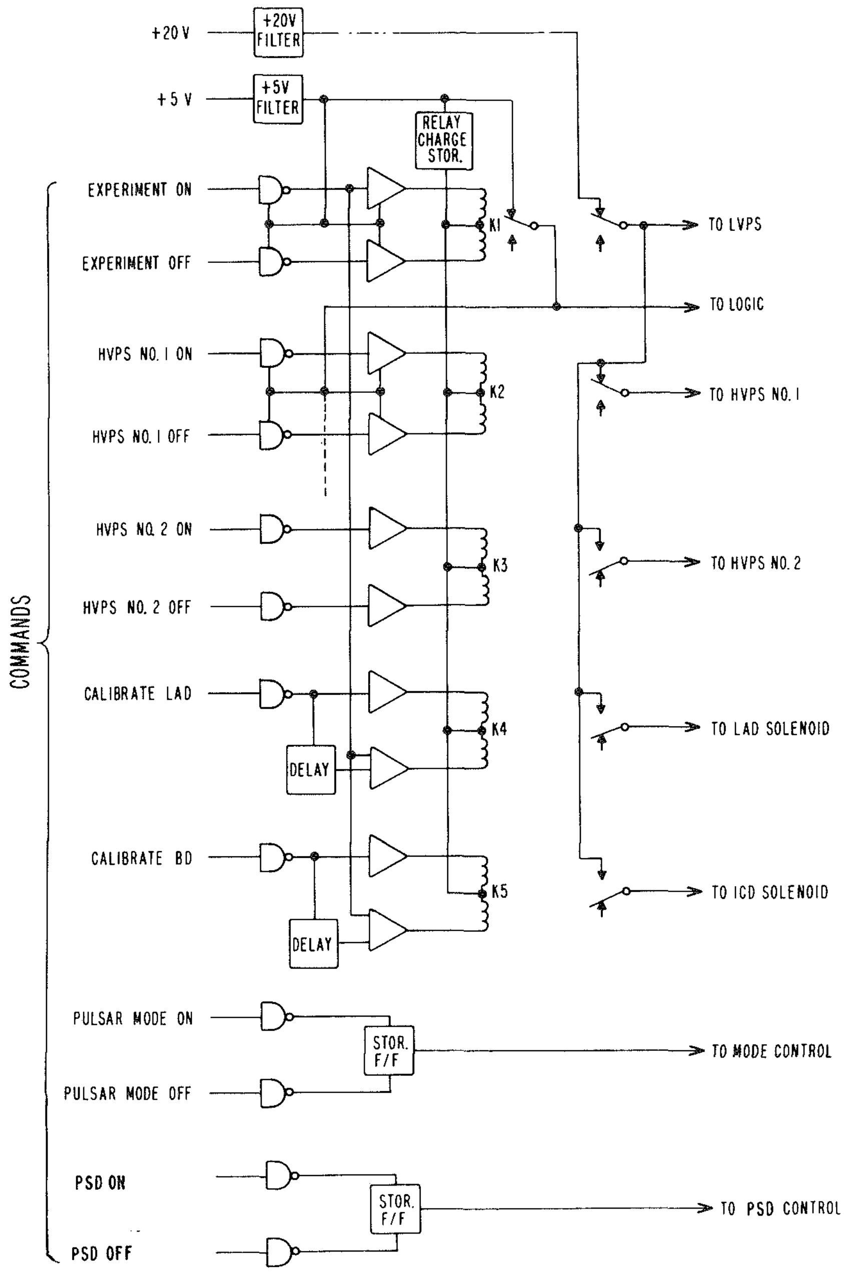
are strobed into a buffer register whose contents are then read out serial bit fashion under control of the spacecraft clock. After the sixteenth bit has been readout the spacecraft may address a another accumulator.

The seven accumulators affected by the PULSAR mode represent the high energy end of the LAD spectrum. In the PULSAR mode, this data is not required and is waived in favor of the time of occurence of each event. Thus, these accumulators switch to counting clock pulses and, as each event occurs, one of the seven accumulators is inhibited, thereby storing the time of occurrence of the event. After telemetry readout, once each second, these accumulators are reset and the sequence of counting time is repeated.

In order to meet the power and volume restraints, the accumulator, will consist of Amelco Ultra Low Power Transistor-Transistor-Logic flip-flop and gate chips mounted in an 18-pin hybrid MSI package. The result will be an 8-bit accumulate and transfer function dissipating less than 6 milliwatts and occupying a volume less than one-fifth of the equivalent Small-Scale Integrator design.

4.5 Power and Command Distribution

The experiment will resolve unswitched power from the spacecraft in the form of regulated +5 volts and regulated +20 volts. In addition, the Experiment will receive commands for the distribution of this power and the control of the experiment as nominal +5-volt logic pulses of approximately 10 to 20 milliseconds in duration. The power and command distribution subsystem will interface with the spacecraft commands using Texas Instruments SN54L00. Those associated with the experiment ON and OFF commands are powered at all times.



NOTES

1. ISOLATION BETWEEN +20V AND +5V
2. COMMANDS ARE +5V PULSES APPROXIMATELY 10ms DURATION
3. ONLY ONE FILTER FOR ALL CONVERTERS
4. INTERFACE LOGIC ELEMENTS ARE SN54L00 BY T I
5. EXPERIMENT "ON" COMMAND POSITIVELY RESETS CALIBRATE MODES
6. K1 THROUGH K5 ARE MAGNETIC LATCHING RELAYS

Figure 4-5. Power and Command Distribution

While not shown in Figure 4-5, the low voltage power supply is also a part of this system. It supplies $\pm$ 6.75 volts to the preamplifiers and each analog circuitry at an efficiency of about 70%. The high voltage power supply is considered to be a part of the detector electronics function.

Both the HVPS and LVPS receive input power from the Spacecraft +20 V buss.

4.6 Calibration

The calibration sources, mounted on the rods in front of each detector, will be actuated by rotary solenoids. On command, these are rotated into position for a short period of time and provide a front-to-end calibration of the system.

4.7 Electronics Packaging

An open-frame structure will be used to mount the electronics and also to serve as mechanical interface and thermal path to the main structure, as shown in Figure 4-6.

The Module Bank Assembly packaging utilizes standard soldered cordwood construction techniques. Components such as glass diodes and capacitors which are sensitive to thermal gradients are coated with a semi-rigid potting compound to provide a buffer between component and final encapsulant. The entire module, except terminals, are encapsulated with an epoxy compound, Stycast 1090, providing a high degree of environmental protection and support for components and interconnections. Electrical components having critical operating temperatures are positioned as near as possible to thermally controlled surfaces. The cordwood modules are mounted on printed circuit cards with Flexprint used to interconnect the printed circuit cards.

The basic design of the Planar Electronics is the "Integrated Circuit Stick" whose packaging advantages are:

- Minimum weight
- Smallest volume.
- Maximum reliability.
- Highest performance achievable.

The "Integrated Circuit Stick" will be mechanically and electrically mounted to a mother-board which will also interface with the open frame structure.

The Low Voltage Power Supply electronics are packaged as a modular unit which is mounted in line with the integrated circuit sticks, and is located to provide efficient power distribution to the Modular Bank Assembly, the Planar Electronics Assembly and the preamplifiers.

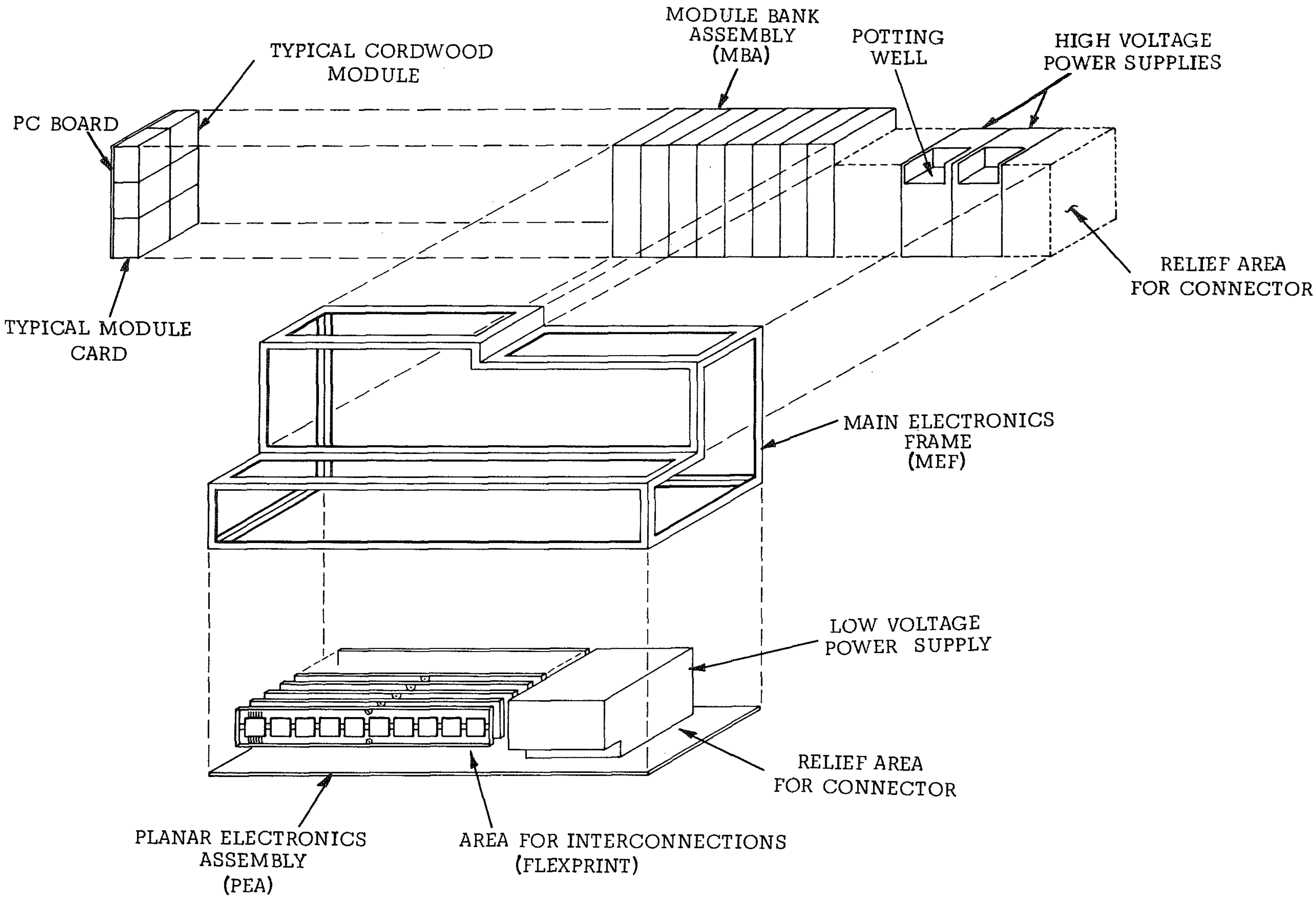


Figure 4-6. Packaging for ANS Hard X-Ray Experiment Electronics

5.0 GROUND SUPPORT EQUIPMENT

5.1 General Description

The Ground Support Equipment will provide a system for the complete checkout of the experiment. It will be suitable for the support of pre-integration engineering, qualification and acceptance testing of the experiment independent of spacecraft support.

Typical Test Sequence

The experiment will be supported with standard laboratory test equipment cables, handling fixtures, and special optical or other alignment and calibration equipment which is not expected to be needed for continuous field support. The test equipment will, however, be used continuously as support from the beginning of engineering tests up through pre-integration tests. A typical non-specific test sequence which might be conducted is described below to indicate equipment usage.

(1) Turn on primary power and perform housekeeping voltage limit check and record data.

(2) Activate S/C commands, setting the experiment into the desired operational mode.

(3) Provide a simulated signal input to the summing point of the detector outputs. Issue commands to inhibit PSD. Change rise time listing.

(4) Collect comparison data and calculate PSD rejection ratio and print listing.

The two sets of GSE will be of the suitcase type of equipment used to trouble shoot experiment malfunctions. It is anticipated that integrated tests will consist of exercising the experiment via the command link and utilizing the on-board calibration rods.

Integration and Field Support

Following delivery of the prototype and flight models, field

support consisting of qualified scientific and engineering personnel will be provided at the Netherlands Consortium Integration Facility to accompany the experiment through the integrated tests programs. Upon arrival prior to spacecraft integration the experiment will be subjected to a transportation survial checkout using the GSE. Upon completion of this checkout, the AS&E field personnel will provide the Dutch with close support in the assembly, alignment and integration of the experiment with the ANS Spacecraft.

Field support will be provided to support pre- and post-launch test and evaluation activities at the Western Test Range. The GSE used at the launch site will permit testing to determine suitability of the experiment for launch. Post-launch support will be provided for a maximum to two weeks after launch to evaluate the condition of the experiment during the immediate post-launch period.

6.0 TESTING AND INTEGRATION

6.1 Qualification and Acceptance Testing

Qualification Testing

Qualification tests as defined in the Qualification Test Plan will be performed on the Experiment Prototype Model to demonstrate that the hardware will perform to specified requirements when exposed to the environmental conditions to be encountered during ground-handling and flight. Typically, the environmental levels imposed are moderately above the expected operational environment in order to ensure that design is not marginal for the conditions to be encountered, yet not so severe as to overstress or damage the hardware. Care will be taken to ensure that these tests do not introduce unrealistic failure modes. The qualification tests will include verification that the experiment mechanical and electrical interface meet the interface specification.

Acceptance Testing

Acceptance tests as defined in the Acceptance Test Plan will be performed on the Flight Model of the Experiment. Typically, the environmental levels imposed for acceptance tests are less than the expected operational environment. The primary purpose of these tests is to demonstrate that latent material and workmanship defects have not occurred in the proven design.

The acceptance tests will include verification that the experiment mechanical and electrical interfaces meet the interface specification.

Test Plans

Testing of the Prototype and Flight Models will generally conform to the functional and environmental requirements given in "General Environmental Test Specification for Spacecraft and

Components," GSFC S-320-G-1, October, 1969. Test plans will be prepared for approval by GSFC, defining specific environmental test and test criteria for all phases of Qualification and Acceptance Testing.

Test Procedures

Qualification and Acceptance Test Procedure documenting the equipment requirements and test methods suitable for use by engineering level personnel will be prepared.

The ground-support equipment described in this proposal will be used to perform the qualification and acceptance tests. Test procedures and test-data documentation will take full advantage of the capabilities of the GSE to record test chronology and results.

6.2 Instrument Calibration

Primary calibration of the instrument sensitivity, energy resolution, angular resolution, and background levels will be performed under a controlled environment using both optical and x-ray techniques. Secondary calibrations and functional checks will be performed using the GSE provided. In-flight calibration of the detectors will be performed using the calibration rods as a calibration source.

6.3 Integration and Field Support

Following delivery of the prototype and flight models, field support consisting of qualified scientific and engineering personnel will be provided at the Netherlands Consortium Integration Facility.

Field support will be provided to support pre- and post-launch test and evaluation activities at the Western Test Range. The GSE used at the launch site will permit a Go/No-Go test to

determine suitability of the experiment for launch. Post-launch support will be provided for a maximum of two weeks after launch to evaluate the condition of the experiment during the immediate post-launch period.

7.0 EXCEPTIONS

The following specific exceptions are taken to the Statement of Work:

Size (3.2.1)

Exception is taken to the volume of 4000 cm^3. The rectangular configured volume, not including connectors, shall not exceed 34 cm x 24 cm x 12 cm.

Power Input (3.3.2)

Exception is taken to the average power requirement of 2 watts. The average power requirement for the experiment shall not exceed 3 watts (2 watts at 20 volts and 1 watt at 5 volts).

Temperature (3.3.7)

Exception is taken to the requirement for design of experiment to operate over a temperature range of $-20^{\circ}C$ to $+50^{\circ}C$. The experiment shall be designed to operate over a temperature range of $0^{\circ}C$ to $40^{\circ}C$. A shipping container will be provided to maintain this range during transportation and storage. Storage or operation of the proportional counters at temperature extremes can result in degradation. At temperatures in excess of $40^{\circ}C$, permanent reduction in gain of the proportional counter can result. The sealing properties of epoxies at temperatures between $0^{\circ}C$ and minus $50^{\circ}C$ are not well know, but the failure mode is usually cracking of the epoxy. Cracks will result in leaks in the proportional counters. As such, exception is taken to exposing the proportional counters to temperature limits which exceed $0^{\circ}C$ and $40^{\circ}C$ during temperature and thermal-vacuum tests.

Humidity (3.3.9)

Exception is taken to humidity tests because of potential catastrophic failure of the detectors due to corrosion of the thin beryllium windows.

The detectors will be stored, transported, and handled in a controlled humidity environment. The relative humidity levels should not exceed 55%, although the detectors can tolerate levels of 70% relative himidity for short periods of time.

It is known that beryllium in the presence of moisture and either chloride or sulphate ions will be attacked by galvanic action set up with the impurities in the beryllium. The corrosion results in small pits which, in the case of thin foil used in the detectors, are of sufficient depth to cause porosity and subsequent failure of the detector. Obviously, the extent of the corrosion is a function of time, temperature and the amount of moisture present. There is very little data available, however, upon which an accurate assessment of the effect of each of these variables can be made.

Vacuum (3.3.8)

Exception is taken to the requirement for the testing at partial pressures where Corona can occur. The experiment will be designed to be Corona-free and to survive a Corona environment, but it will not be tested at partial pressures where Corona can occur for the following reasons:

(1) The operational pressure levels for the experiment are less than 10^{-5} Torr, well below the Corona region.

(2) Experience with flying spacecraft and command coding and decoding systems has borne out the theoretical conclusion that the probability of accidental turn-on is essentially zero. Therefore, the risk of operating in the Corona region is minimal.

(3) Unnecessary exposure to a Corona environment compromises the experiment in that subtle damage or degradation may occur which is not immediately detectable.

APPENDIX A
ANS HARD X-RAY EXPERIMENT
SPECIMEN OBSERVING PLAN

INTRODUCTION

The following observing plan is a sample of the types of observations desired by the hard x-ray experimenters on the Astronomical Netherlands Satellite.

The observational targets were selected from the catalogue of 33 previously observed x-ray sources and from a simulated x-ray source catalogue which was generated at AS&E for planning x-ray observing programs. A simulated catalogue is necessary at this point in time because many x-ray observations done by the ANS will be on objects we expect to discover in future all-sky surveys to be done by satellites in 1970-1971. The observing period is the first week of September 1970 as agreed at the Preliminary Design Review in April 1970.

The observing program lists six individual observations (three previously observed sources and three simulated sources) during that week. Two additional pulsar sources (simulated) are to be observed only if telemetry on two successive orbits becomes possible. The time outline shows a total of 87 hours, slightly in excess of the 84 hours normally allotted to x-ray observations (50% of the 168 hours in a week). We expect some of our observations could be timed to appear in the same orbit as an ultra-violet observation in nearly the opposite direction. If so, time could be trimmed from the scan mode (source #9) to yield 84 hours. The requested observing time includes any time spent at polar latitudes in the orbit. We are not sure how much of that time will be lost due to high background; we would like to be notified about the amount of time spent above $\pm 30^{\circ}$ and $\pm 40^{\circ}$ for each observation scheduled in the final program.

The coordinates used are epoch 1950 for both the sources and the guide stars, whereas the sun's ephemeris is in epoch 1970 coordinates. The uncertainties in the positions of the three previously observed objects is larger than the difference between the coordinate systems, and the simulated catalog may just as well be assumed in one coordinate system as another. Switching the coordinate system to epoch 1970 would change the time of first and last visibility by 6.7 hours. The time is ephemeris time which differs from universal time by less than 1 minute.

The time outline represents one way the observations can be assigned to particular days. Any other arrangement which fits the requested time within the appropriate windows is acceptable also.

TIME OUTLINE

Date September 1970	Observation (source number)	Requested Duration (hours)
1	1 and 2[a]	12
2	3 (pulsar)	12
3	4 and 9[b]	21
4	None	
5	6 and 9[b]	9
	7 and 9[b]	12
6	7 and 9[b]	21
7	None	—
	Total	87

Additional pulsar observations if telemetry on two successive orbits becomes possible:

4	5	3
5	5	3
6	8	3
7	8	3
	Total	12[c]

a) #1 and #2 can be observed during the same orbits because they are in nearly opposite directions.

b) #9 is the scan mode which is to be used when the main object is occulted by the earth. Since scanning is our lowest priority observation, it can be cut down to allow for other observations.

c) These 12 hours may be taken from our other observations if telemetry on two successive orbits becomes possible.

Source #1

1. Object Name: None

2. Cel. Coord: $16^h 14^m$ Ecl. Coord: $\lambda = 248.78^\circ$
   $-39^\circ 31'$ $\beta = -18.00^\circ$

3. Observing Time: first visible: Aug. 31 13:47
   last visible: Sept. 2 17:55
   window : 52.1 hours
   time requested: 12 hours
   8 orbits, 40 min, each.

4. Spacecraft Mode: Pointing, X-ray, no offset

5. Experiment Mode: Bragg using normal processing mode

6. Attitude Control Requirements:

   pointing accuracy: 1'
   pointing record : sun and star sensors
   orbit ephemeris : about 1° accuracy

7. Data Retrieval and Memory Requirements:

   The normal processing mode uses 3.5 bits/sec. (two 16 bit words every 16 sec and 24-16 bit words every 256 sec.) 8400 bits are stored in the memory during the 40 min of each orbit the normal processing mode is used. Therefore, in eight orbits 67,000 bits are used for this source and 67,000 more for source #2 observed in the same orbits, making a total of 134,000 bits.

Source #2

1. Object Name: GX 135 + 11.4 (from simulated x-ray source catalog)

2. Cel. Coord: $3^h\ 15^m\ 3^s$ Ecl. Coord: $\lambda = 70.09^\circ$
   $70^\circ\ 36'\ 31''$ $\beta = 50.00^\circ$

3. Observing time: first visible: Sept. 1 09:49
   last visible: Sept. 4 14:54
   window : 77.1 hours
   time requested: 12 hours
   40 min. of each of 4 orbits on source and 40 min. of each of 4 orbits on background. Offset 20' from source

4. Spacecraft Mode: Pointing, star

   Guide stars: SAO # 004891 Mag. = 7.4 $\Delta\lambda$ = 38.7' $\Delta\beta$ = 21.4' (for source)
   38.7' $\Delta\beta$ = 41.4' (for bkgr)
   SAO # 012676 Mag. = 7.7 $\Delta\lambda$ = -54.0' $\Delta\beta$ = -37.8' (for source
   -54.0' $\Delta\beta$ = -17.8' (for bkgr)

5. Experiment Mode: Spectral content measurement using normal processing mode

6. Attitude Control Requirements

   Pointing accuracy : 2'
   Pointing record : sun and star sensors
   Orbit ephemeris : about 1° accuracy

7. Data Retrieval and Memory Requirements:

   See Source #1

Source #3

1. Object Name: GX 143 + 05.9 (from simulated x-ray source catalog)

2. Cel. Coord: $3^h\ 50^m 14^s$ Ecl. Coord: $\lambda = 70.30^\circ$
$61^\circ\ 11'\ 53''$ $\beta = 39.95^\circ$

3. Observing Time: first visible: Sept. 1 21:08
last visible: Sept. 4 14:45
window : 64.6 hours
time requested: 12 hours

4. Spacecraft Mode: Pointing, Star

Guide Stars: SAO# 012968 Mag = 5.2 $\Delta\lambda = + 20.0'$ $\Delta\beta = - 18.9'$
SAO# 012922 Mag = 7.4 $\Delta\lambda = - 30.4'$ $\Delta\beta = + 35.0'$

5. Experiment Mode: Pulsar mode #1 (i.e., time-tagging each photon.)

6. Attitude Control Requirements:

Pointing accuracy: 2'
Pointing record : sun and star sensors
Orbit ephemeris : about 1° accuracy

7. Data Retrieval and Memory Requirements:

The present design calls for a bit rate of 83/sec (five 16-bit words every second, two 16-bit words every 16 seconds, and nineteen 16-bit words every 256 seconds). AS&E's share of the memory (160,000 bits) will be filled in 36 minutes. The remaining portion of the 12 hours between telemetry readouts will be wasted. Truncation of the 16-bit words to 10 bits by the on-board computer may reduce the bit rate.

Source #4

1. Object Name: SCO XR-4

2. Cel. Coord: $16^h 25^m$ Ecl. Coord: $\lambda = 251.06^o$
-40^o $\beta = -18.10$

3. Observing Time: first visible: Sept. 2 22:15
last visible: Sept. 5 02:21
window : 52.1 hours
time requested: 21 hours
14 orbits, 50 min. each.

4. Spacecraft Mode: Pointing, X-ray, no offset

5. Experiment Mode: Bragg using normal processing mode

6. Attitude Control Requirements:

   Pointing accuracy: 1'
   Pointing record : sun and star sensors
   Orbit ephemeris : about 1^o accuracy

7. Data Retrieval and Memory Requirements:

   The total bit useage rate is 3.50 bits/sec, the same as for source #1

   10,500 bits are stored in the memory during the 50 min of each orbit the normal processing mode is used. Therefore, in eight orbits 84,000 bits are used. The scan mode (source #9) used during the fraction of each orbit that this source is not visible, accounts for an additional 67,000 making a total of 151,000.

Source #5

This source is to be observed only if telemetry on two successive orbits becomes possible.

1. Object Name: GX 341 + 04.5 (from simulated x-ray source catalog)

2. Cel. Coord: $16^h28^m18^s$ Ecl. Coord: $\lambda = 251.97^\circ$
   $-41^\circ 27'11''$ $\beta = -19.43^\circ$

3. Observing time:

first visible:	Sept. 3 20:38
last visible:	Sept. 6 00:58
window :	52.3 hours
time requested:	6 hours

   This source is to be observed for 50 min during each of four orbits in which the satellite passes over the receiving station.

4. Spacecraft Mode: Pointing, star

   Guide stars:

SAO #226855	Mag = 5.5	$\Delta\lambda$ = + 1.6'	$\Delta\beta$ = -15.4'
SAO #226814	Mag = 7.2	$\Delta\lambda$ = - 29.4'	$\Delta\beta$ = +22.8'

5. Experiment Mode: Pulsar mode #1 (i.e., time-tagging each photon.)

6. Attitude Control Requirements

   Pointing accuracy : 2'
   Pointing record : sun and star sensors
   Orbit ephemeris : about 1° accuracy

7. Data Retrieval and Memory Requirements:

   The present design calls for a bit rate of 83/sec. AS&E's share of the memory will be filled in 36 minutes. Truncation by the on-board computer may reduce the pulsar bit rate. If so, 50 minutes of observation would be possible.

Source #6

1. Object Name: GX 341 + 03.7 (from simulated x-ray source catalog)

2. Cel Coord: $16^h\ 30^m\ 57^s$ Ecl Coord: $\lambda = 252.60^\circ$
   $-42^\circ\ 8'\ 38''$ $\beta = -20.03^\circ$

3. Observing Time: first visible: Sept. 4 12:12
   last visible: Sept. 6 16:52
   window : 52.7 hours
   time requested: 9 hours
   6 orbits, 50 min. each.

   3 orbits to be spent looking at source and 3 orbits to be spent looking at background offset 30' from source.

4. Spacecraft Mode: Pointing, star

   Guide stars: SAO# 226813 Mag = 5.0 $\Delta\lambda = -40.1'$ $\Delta\beta = +\ 3.8'$ (for source)
   $\Delta\lambda = -40.1$ $\Delta\beta = +\ 33.8$ (for bkgr)

   SAO# 226892 Mag = 7.5 $\Delta\lambda = +\ 9.7'$ $\Delta\beta = -\ 7.8'$ (for source)
   $\Delta\lambda = +\ 9.7$ $\Delta\beta = +\ 22.2$ (for bkgr)

5. Experiment Mode: Spectral content measurement using normal processing mode.

6. Attitude Control Requirements:

   Pointing accuracy : 2'
   Pointing record : sun and star sensors
   Orbit ephemeris : about 1° accuracy

7. Data Retrieval and Memory Requirements:

   Same as source #4

Source #7

1. Object Name: NOR XR-1

2. Cel Coord: $16^h 24^m$ Ecl Coord: $\lambda = 252.99^\circ$
-51° $\beta = -28.96^\circ$

3. Observing time:

first visible:	Sept. 4 19:48
last visible:	Sept. 7 04:20
window:	56.5 hours
time requested:	33 hours
	22 orbits, 50 min. each.

4. Spacecraft Mode: Stepping - 11 steps each a 1' change in β, centered about the position given by the guide stars.

SAO # 243900	Mag = 7.7	$\Delta\lambda$ = +30.9'	$\Delta\beta$ = + 13.4'
SAO # 243873	Mag = 7.5	$\Delta\lambda$ = +21.9'	$\Delta\beta$ = - 24.4'

Each step to last 2 orbits (3 hours).

5. Experiment Mode: Bragg using normal processing mode.

6. Attitude Control Requirements:

Pointing accuracy: 1'
Pointing record : sun and star sensors
Orbit ephemeris : about 1° accuracy

7. Data Retrieval and Memory Requirements:

Same as source #4.

Source #8

This source is to be observed only if telemetry on two successive orbits becomes possible.

1. Object Name: EGX 258 + 29.1' (from simulated x-ray source catalog)

2. Cel. Coord: $17^h 13^m 3^s$ Ecl. Coord: $\lambda = 253.28^\circ$
   $29^\circ 3' 27''$ $\beta = 51.82^\circ$

3. Observing time:

first visible	: Sept. 4	15:11
last visible	: Sept. 7	23:14
window	: 80.0 hours	
time requested	: 6 hours	

   This source is to be observed for 50 min during each of the four orbits in which the satellite pases over the receiving station

4. Spacecraft Mode: Pointing, Star

   Guide Stars:

SAO #084983	Mag. = 7.1	$\Delta\lambda$ = +55.4'	$\Delta\beta$ = -1.2'
SAO #084990	Mag. = 7.6	$\Delta\lambda$ = 62.8'	$\Delta\beta$ = 1.0'

5. Experiment Mode: Pulsar Mode #1 (i.e., time-tagging each photon)

6. Attitude Control Requirements

   Pointing Accuracy : 2'
   Pointing Record : Sun and star sensors
   Orbit Ephemeris : About 1° accuracy

7. Data Retrieval and Memory Requirements

   Same as source #5.

Source #9

1. Object Name: Scan

2. Coordinates:

3. Observing Time:

   During each orbit for which the main purpose is to observe one of five following objects, the satellite will scan along the horizon when that primary object is occulted by the earth. At the time the primary object is first occulted the satellite is to be rapidly turned to the other horizon where it scans at a rate of about 4°/min with a constant offset to the horizon. After about 35 min the primary object is re-acquired and we return to its observation.

4. Spacecraft mode:

   Fixed elevation scan, horizon angle = $\sim 10^{\circ}$

5. Experiment mode:

   High rate accumulation mode.

6. Attitude Control Requirements:

   Pointing accuracy: 0.3°

   Pointing record : sun and horizon sensors

   Orbit ephemeris : better than 0.3° accuracy

7. Data Retrieval and Memory Requirements:

   Every 4 sec the computer samples the accumulators for the two large area detectors using only 8 bits of each accumulator. The bit useage is therefore 4 bits/sec. During the 35 min of each orbit that the high rate mode is used, 8,400 bits of memory will be filled up. In the 8 orbits between successive read-outs 67,000 bits are used. An additional 84,000 bits are accounted for by the normal mode, making a total of 151,000 for each read-out.

PART II. PROGRAM MANAGEMENT

1.0 PROGRAM MANAGEMENT

This experiment presents the integrated efforts of two scientific groups - x-ray astronomers at both American Science & Engineering, Inc., and at the Massachusetts Institute of Technology. The management philosophy for this effort will afford the Principal Investigator, Principal Scientist, and the Co-Investigators as much scientific freedom as possible within the program schedule and cost. The Principal Investigator at AS&E and the Principal Scientist at MIT will coordinate and control the scientific objectives and, in conjunction with the Program Manager at AS&E, will be responsible for designing, developing, fabricating, testing and delivering a qualified flight instrument.

The Program Manager at AS&E will be responsible for translating the AS&E/MIT Scientific Specification into the instrument baseline design and the Interface Control Documentation. The Program Manager will provide technical, fiscal, and schedule direction, monitor the results of this direction, institute corrective action where necessary, and determine that the requirements of the program are being satisfied. Formal interfacing with the ANS Project Office and NASA will be performed by the AS&E Program Manager. Program scheduling and report information will also be provided by the Program Manager. Program fiscal reporting will be submitted by the AS&E Contracts Department.

The Program Manager will be supported by the various skill centers at AS&E in the accomplishment of the above responsibilities. The AS&E Program Management, Engineering, Manufacturing, and Quality Control Departments are organized and function in a manner which provides AS&E with the flexibility of successfully conducting complex manned space program, satellite programs, and sounding rocket activities in parallel and with different operating requirements.

At MIT, project support will be oriented primarily toward assisting the Principal Scientist in the research, design, and development of the MIT portion of the instrument, with emphasis on achieving the scientific goals and experimental requirements. AS&E will retain the responsibility for the implementation of all flight hardware.

The following Program Schedule is based on the Statement of Work requirements.

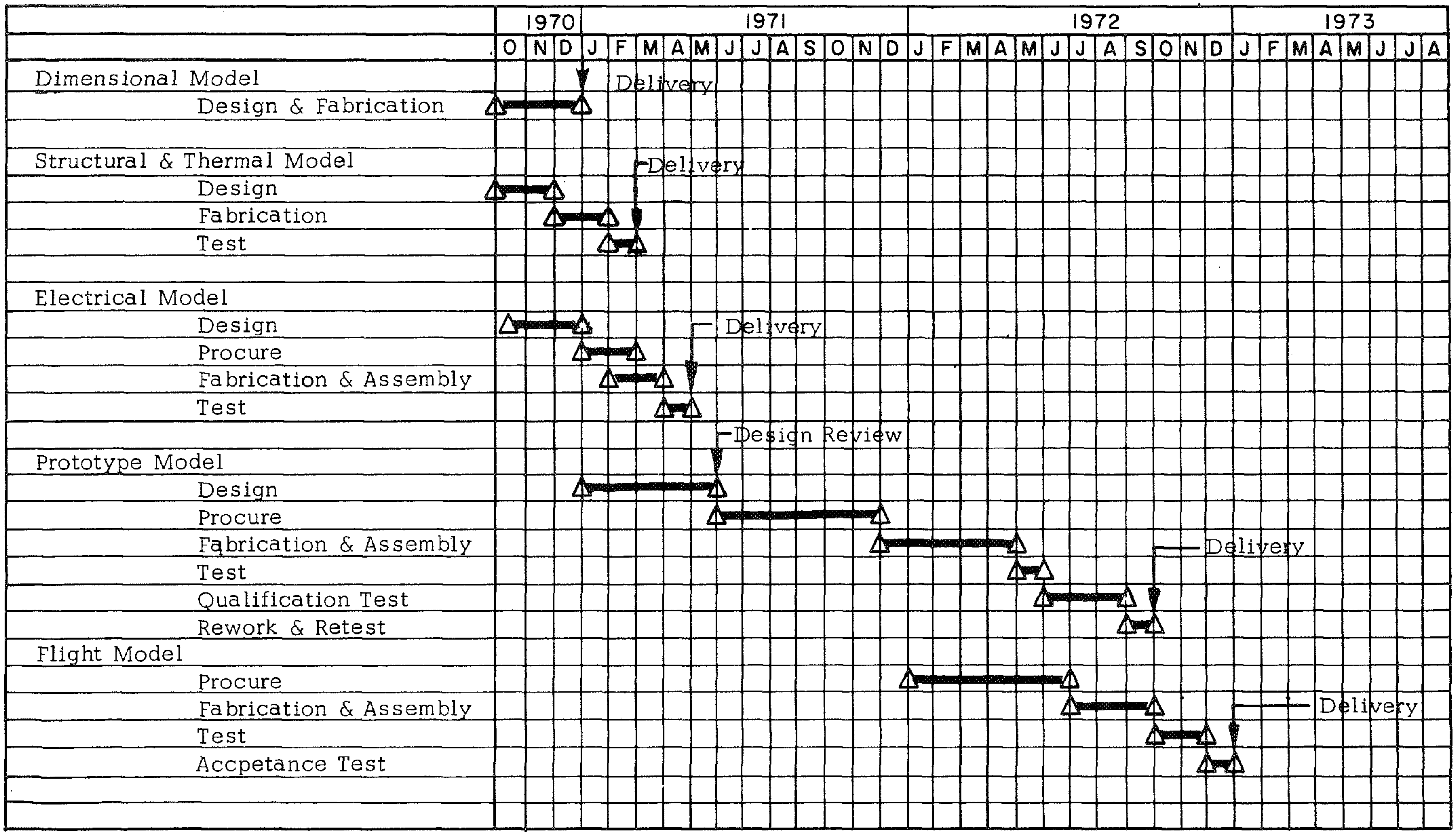


Figure 1-1. Delivery Schedule, ANS Program

2.0 PROGRAM DEFINITION

AS&E will fulfill the requirements of the Statement of Work in accordance with the schedule shown in Figure 2-1. The following identifies the specific delivery requirements for the ANS Program:

2.1 Deliverable Hardware

2.1.1 Dimensional Model (1 unit)

A Dimensional Model (DM) will be fabricated, utilizing the Interface Control Drawing (ICD) which defines the Experiment envelope and mounting dimensions. AS&E will verify that the DM satisfies the ICD in terms of envelope and 'footprint'.

2.1.2 Structural and Thermal Model (1 unit)

A Structural and Thermal Model will be fabricated to the same ICD used for the DM. The STM will be representative of the mass, CG, and thermal load of the Experiment.

2.1.3 Electrical Model (1 unit)

An Electrical Model (EM) will be fabricated to the same ICD used for the DM. The EM will be representative of the experiment in terms of input and output signal characteristics.

2.1.4 Prototype Model (1 system)

The Prototype System will be a complete operating experiment and will comply with released drawings and specifications. The thermal-vacuum portion of the Qualification Tests will be performed at AS&E's facility. All other portions of the Qualification Tests will be performed at GSFC's facility and will conclude with final acceptance at GSFC.

2.1.5 Flight Model (1 system)

The Flight Model will be a complete operating experiment and will comply with released drawings and specifications. The thermal-

vacuum portion of the acceptance tests will be performed at AS&E's facility. All other portions of the Acceptance Tests will be performed at GSFC's facility and will conclude with final acceptance at GSFC.

2.1.6 Ground Support Equipment (2 units)

Two GSE testing units will be fabricated. Released drawings will consist primarily of a system block diagram and schematics for use by AS&E-trained engineers to facilitate troubleshooting. Actual calibration and operational checks of the Experiment will be performed by the spacecraft ground checkout computer.

AS&E proposes a delivery schedule as shown in Figure 1-1. The earlier indicated deliveries of the Prototype and Flight systems will afford a more efficient utilization of manpower.

AS&E does assume that NASA/GSFC will require support in the interim period between delivery of the Flight System and the launch date of the spacecraft. The equivalent of one man-month of labor each month will be available during the interim period. AS&E has also included the equivalent of three man-months of support for the launch support activity.

3.0 WORK BREAKDOWN STRUCTURE FOR THE PROGRAM

In accordance with the program definition and schedules provided in Section 2.0, the activity during this contract phase has been organized into a work breakdown structure (WBS). Each work package within the work breakdown structure is composed of a number of tasks.

Figure 3-1 is a functionally oriented work breakdown structure including hardware, software, and services which defines and graphically displays the work to be accomplished in order to achieve program objectives.

The work breakdown structure is a framework for planning and controlling program cost, schedule, and technical performance at any desired level of the structure. The subdivisions of work identified are manageable units that can be clearly defined, easily related to significant milestone objectives, and effectively estimated and statused. In tracking costs, it is possible to show accumulated charges against any given functional element in the WBS, thereby permitting identification of cost to statement of work elements.

Responsibility for the tasks defined in the work packages is assigned to one person, designated as the Work Package Manager, who is held accountable for the satisfactory completion of those efforts within stipulated cost and schedule parameters.

Work is authorized to each Work Package Manager by release of an Account Distribution Number (ADN). This document is approved by the Program Manager and controlled by the Program Administrator in the Program Office.

The WBS serves as the means for linking diverse elements such as the hardware, software, services, cost and schedule into a common framework. This common framework, against which all program elements may be evaluated and controlled, results in an efficient system of program control and an increased awareness of the scope of system and functional activities.

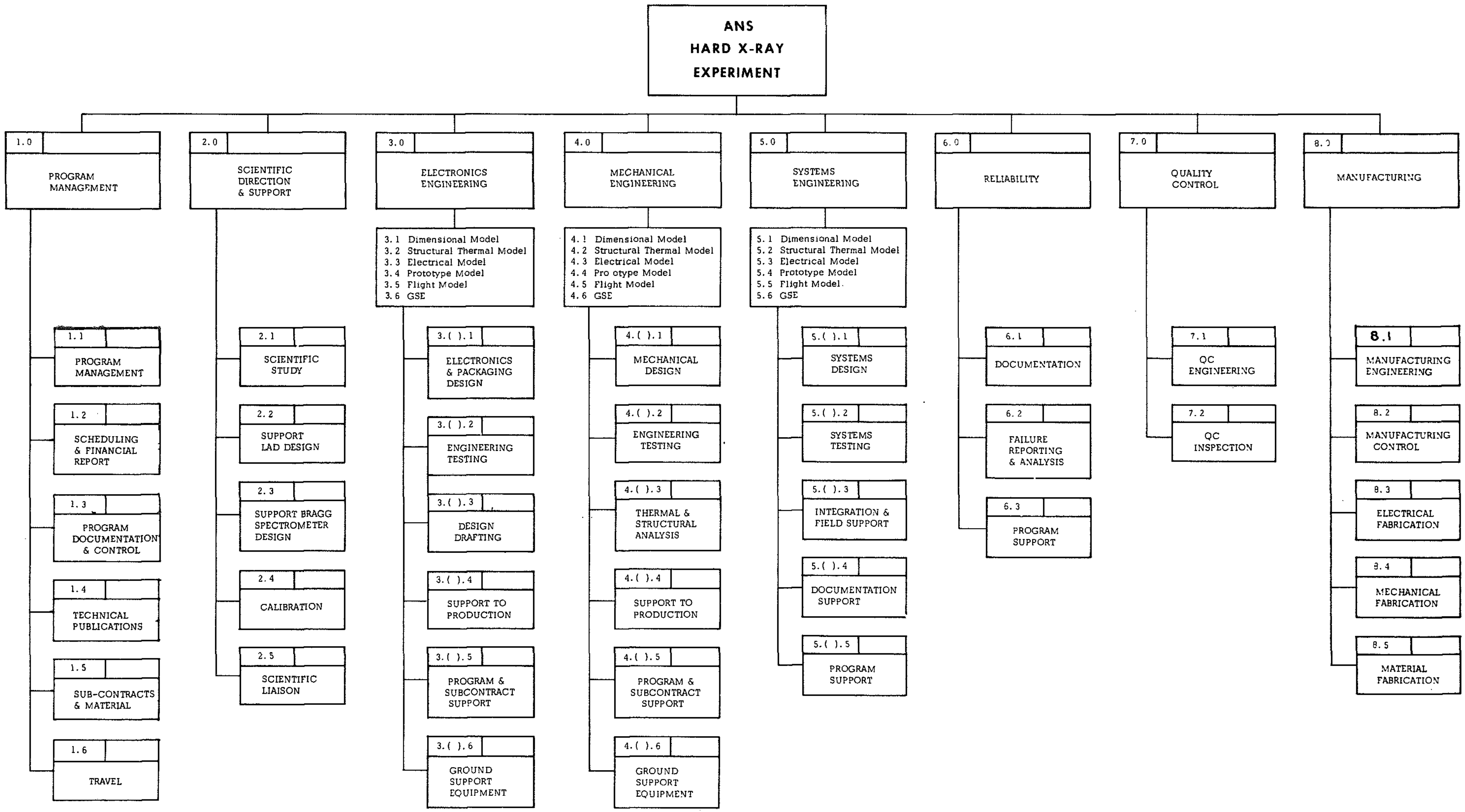


Figure 3-1. Functionally Oriented Work Breakdown Structure for ANS Program

4.0 MANAGEMENT CONTROL

The ANS Program will be managed under a Program Office function. Figure 4-1 is an organization chart of the Space Systems Division of American Science and Engineering showing the assignment of the Program Office. All activities identified as Program Management are the direct responsibility of the Program Office and these include all subcontract and material expenditures as well as certain labor categories such as documentation. The management of the subcontracts such as the MIT subcontract will be the responsibility of the Program Office. The ANS Program Organization Chart is shown in Figure 4-2. The chart lists the various project engineers assigned to each of the disciplines. In view of the program's time span, these project engineers will be assigned only during those periods of the program in which their effort can be utilized most efficiently. Tasks to be performed by the various groups under management of the Program Office are described in Section 5.0.

As described in Section 3.0, the total work to be accomplished on the ANS Program has been divided into a number of functional elements called tasks which have been assigned to the various skill centers within AS&E. Each task is assigned to a Work Package Manager within the skill center and he is the person responsible to the Program Manager for accomplishing that task within the constraints imposed by his task package which is the basic management control tool on the program. Each task package is reviewed by the Program Office and the responsible individual weekly. Each task package is composed of a number of documents which are:

<u>Task Description</u> - A description of all work to be done. These descriptions are in Section 5.0.

<u>Milestone Chart</u> (Figure 4-3) - A schedule for accomplishment of work within the task.

AMERICAN SCIENCE AND ENGINEERING

SPACE SYSTEMS DIVISION

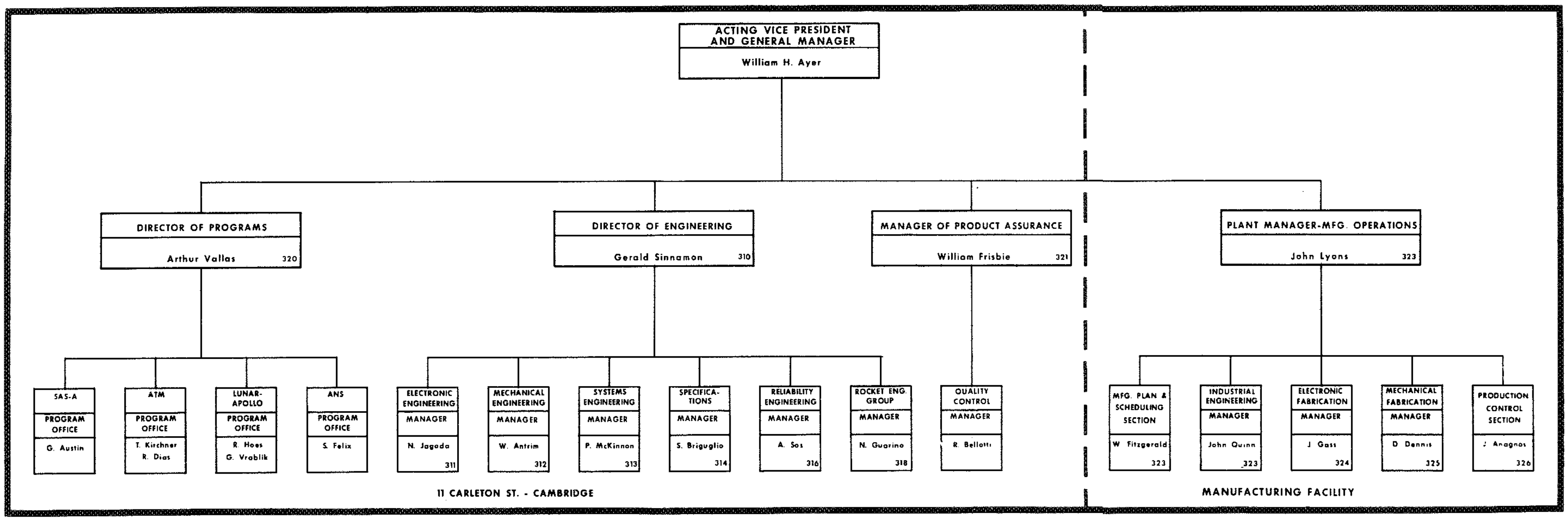


Figure 4-1. Organizational Chart, AS&E Space Systems Division

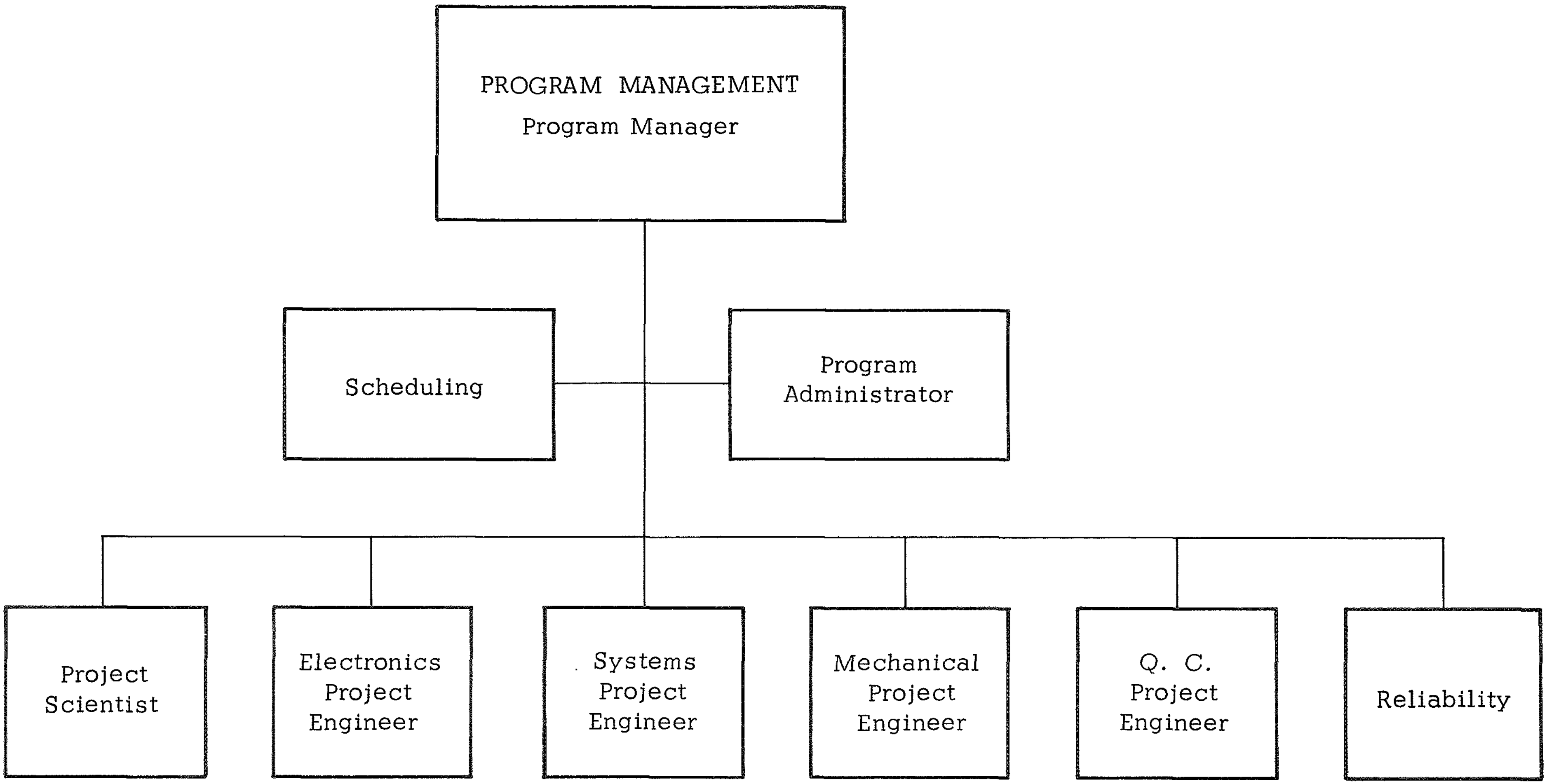


Figure 4-2. Hard X-Ray Experiment Program Organization Chart, ANS Program

AS&E MILESTONE CHART

ORIGINATOR ______

DATE 8 May 1970

PROGRAM ATM

TASK MECHANICAL ENGINEERING STP - PHASE II

SCHED. NO. ______

4.1 Flight System

1970

Task	Task Description
S	Grating Assembly
C	Grating Assembly
S	Grating Calibration
C	Grating Calibration
S	Grating Assy. Rechecked
C	Grating Assy. Rechecked
S	Filter Assembly
C	Filter Assembly
S	Filter Calibration
C	Filter Calibration
S	Filter Assembly - Rechecked
C	Filter Assembly - Rechecked
S	Mirror Partial Assembly
C	Mirror Partial Assembly
S	Mirror Calibration
C	Mirror Calibration
S	Mirror Assembly Total
C	Mirror Assembly Total
S	Mirror Assembly - Vendor Clear
C	Mirror Assembly-Vendor Clear
S	Mirror Assembly-Re-assemble
C	Mirror Assembly-Re-assemble
C	Cable Receipt
S	Housing Assembly
C	Housing Assembly Review
C	Housing Assembly
S	Thermal Control Assy.
C	Thermal Control Assy. Review
C	Thermal Control Assy.
C	Camera Assy. Plate Receipt
S	Camera Assembly

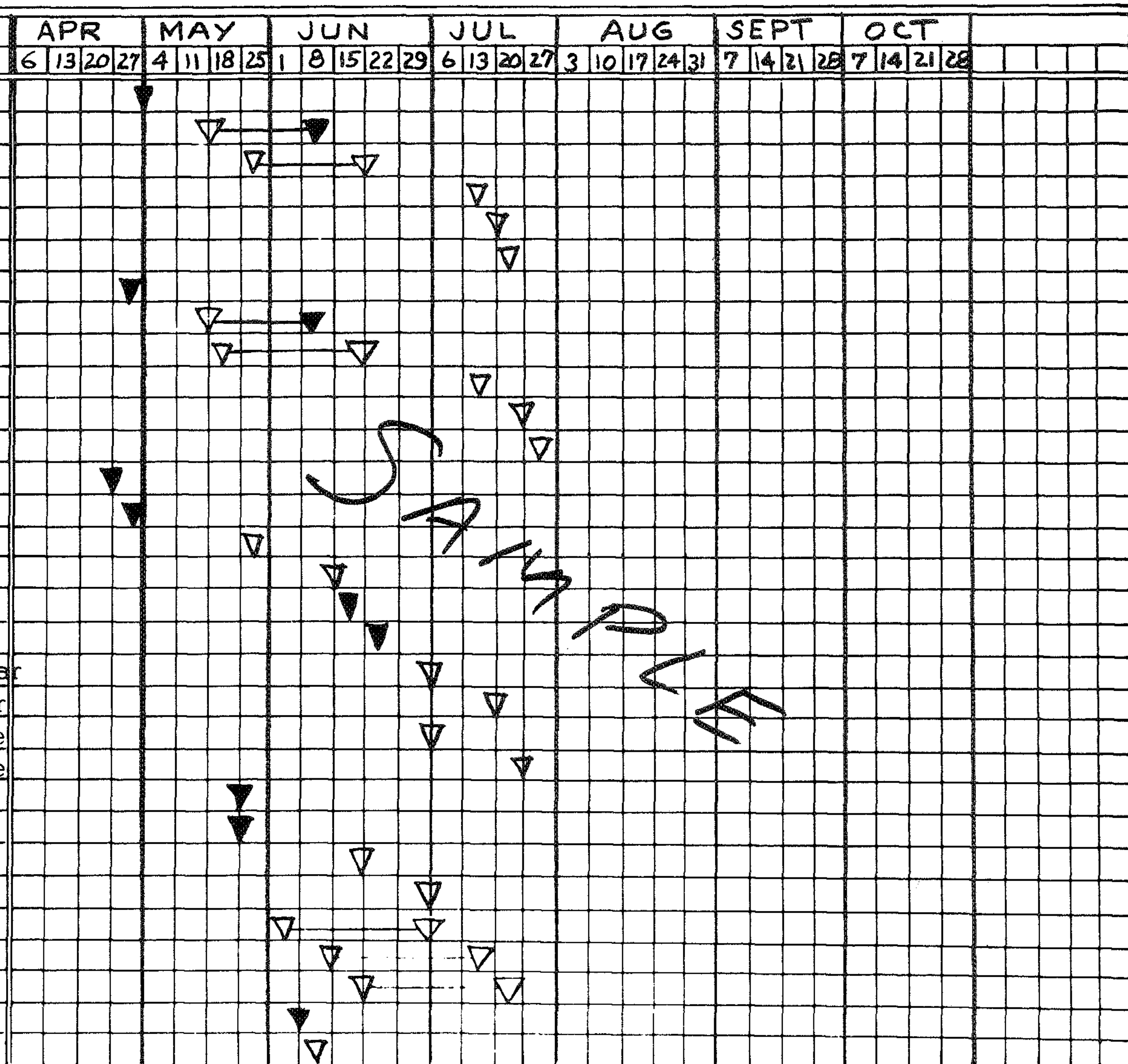


Figure 4-3

F-103

Manpower Loading Chart (Figure 4-4) - A schedule by labor category of all personnel to be used in the accomplishment of the work within the task in man-months per month projected to completion of Phase II.

Manpower Performance Chart (Figure 4-5) - A chart defining the projected average cumulative manpower and weekly manpower required to achieve the defined milestones within a task package. This chart is updated weekly and given to the Program Manager and work package manager to compare labor expended versus milestones achieved. Indications of schedule and/or cummulative manpower performance and milestone performance.

The schedule shown in Section 1.0 will be the basis for a PERT network. The PERT will be submitted bi-weekly to NASA/GSFC.

A financial report will be prepared and submitted weekly to NASA/GSFC.

The individual milestone charts will support the PERT and will contain, in greater detail, the specific events of the task.

The individual manpower loading charts will show the labor required to support the task shown on the milestone chart.

The work packages are summarized to show both schedule and cost performance on a Work Package Summary, Figure 4-6.

Section 9.0 of this proposal contains the manpower loading charts in sufficient detail to delineate the labor required within each work package for the contract deliverable items. Additional details and the accompanying milestone charts will be prepared upon initiation of this phase of the contract.

MANPOWER LOADING CHART

ORIGINATOR J. Murphy

DATE 30 April 1970 (Effective)

PROGRAM ATM (S-054) **TASK** Program Summary **ADN NO.** 643-7XX

Task	Description	Cat.	M	I	J	A	S	O	Addl	
1.0	Program Management	T	9.3	9.3	9.3	9.3	9.0	4.5	-	50.7
2.0	Scientific Direction & Supp.	T	8.2	8.2	8.2	8.2	8.2	4.4	-	45.4
3.0	Electronics Engineering	T	9.4	8.6	9.1	11.1	9.7	2.4	0.5	50.8
4.0	Mechanical Engineering	T	4.3	3.7	3.5	2.8	2.7	1.4	5.7	24.1
5.0	Systems Engineering	T	9.2	8.4	9.8	6.1	8.1	5.9	12.8	60.3
6.0	Reliability Eng. & Doc'n	T	4.5	3.3	1.8	2.3	1.3	0.4	-	13.6
7.0	Quality Control	T	7.0	6.0	6.0	5.0	3.0	1.5	-	28.5
8.0	Manufacturing Operations	T	20.1	15.9	11.8	6.2	-	2.3	-	56.3
	TOTAL PROGRAM: PROJECTED MANPOWER	T	72.0	63.4	59.5	51.0	42.0	22.3		329.7
	ACTUAL MANPOWER:	T	66.6							

SAMPLE

Figure 4-4

F-103A

MANPOWER PERFORMANCE CHART

PROGRAM: ATM (S-054)

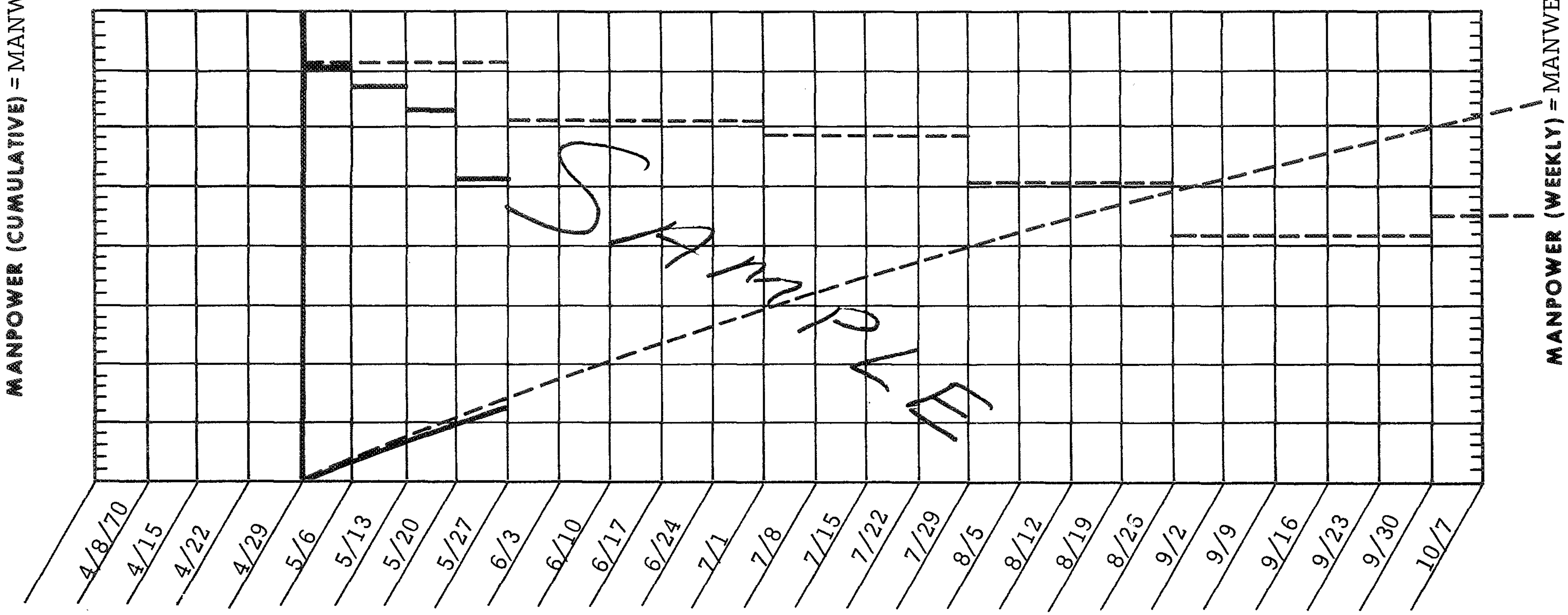
TASK: Total Program Summary - Phase II

ADN: 643-7XX

RESPONSIBILITY: T. Kirchner

DATE OF ISSUE: 30 April 1970

PERIOD OF PERFORMANCE: 4/30/70 - 10/14/70 (Plus Refurb. Effort - Post-October



- - - - Budget
——— Actual

* + 76 M/W Post-Oct.

Figure 4-5

AMERICAN SCIENCE AND ENGINEERING

WORK PACKAGE SUMMARY

PAGE ___ OF ___

TITLE ATM (S-054) - PHASE II COMPLETION

STATEMENT OF WORK

TOTAL PROGRAM SUMMARY

MILESTONE TITLE		1970 J	F	M	A	M	J	J	A	S	O	N	D	1971 J	F	M	A	**
Qualification Testing Complete						▽												
Flight System - Fabrication Complete								▽										
Flight System Accept. Test Complete										▽								
Proto. Retrofit MEA Delivery												▽						
C & D Spare Assemblies (2) Complete												▽						
Refurbished System **																		▽
ECE/SCOTS II Complete								▽										
MILESTONE PERFORMANCE	SCHED.					158	105	101	75	38	45		Addl					
	COMP.					141												
MONTHLY EXPENDITURE ($in 000's)	BUDGET					436	342	189	189	165	62		88					1471
	ACTUAL					308												
MANPOWER EXPENDITURE	BUDGET					72	63	60	51	42	23		19					330 M/M
	ACTUAL					67												
CUMULATIVE % COMPLETION ($)	BUDGET					30	53	66	79	90	94		100					100 %
	ACTUAL					21												

SAMPLE

** To be determined.

Figure 4-6

F-288

5.0 TASK DESCRIPTIONS

The following paragraphs describe the ANS Program tasks to be performed by the various departments and groups.

5.1 Program Management

The Program Office will direct the activities and manage the resources at its disposal to meet the objectives of the contract. Specifically, the following tasks will be performed:

5.1.1 (a) Provide technical direction by means of meetings, directives, and specifications.

(b) Provide program management by means of the program and company organizations, the provisions in this management plan, and management directives.

(c) Conduct liaison with NASA/GSFC for purposes of reporting and obtaining direction as required by the contract.

(d) Provide handling and disposition of technical correspondence, both incoming from and out-going to NASA/GSFC.

(e) Provide authorizations as required for performance of work and placement of orders and subcontracts.

(f) Establish policies and procedures for the program as derived from the contract, company policy and NASA/GSFC direction.

(g) Disseminate information and data as required by the various program disciplines in the performance of their tasks.

(h) Provide direction to production.

5.1.2 (a) Perform reporting and submit documents as required by the contract.

(b) Utilizing a Work Breakdown Structure, establish schedules and cost control reporting to enable the evaluation of progress made with resources spent.

5.1.3 (a) Provide program and hardware control through issuance of required documents.

(b) Insure maintenance of configuration control.

5.1.4 Provide required technical publications.

5.1.5 Perform subcontract management.

5.1.6 Regulate, control, and coordinate program travel.

5.2 Scientific Direction and Support

The following scientific effort will be directed and conducted by the ANS Project Scientist.

5.2.1 Provide required scientific direction and theoretical studies.

5.2.2 Support design of large area detector.

5.2.3 Support design of Bragg Spectrometer, including liaison with MIT.

5.2.4 Perform calibration of proportional counters and the two detector assemblies.

5.2.5 Support NASA/GSFC scientific liaison requirements.

5.3 Electronics Engineering

5.3.1 Dimensional Model
5.3.2 Structural Thermal Model
5.3.3 Electrical Model
5.3.4 Prototype Model
5.3.5 Flight Model
5.3.6 Ground Support Equipment

5.3.( ).1 Electronic and Packaging Design

Design, develop, and test the electronics required to meet the experiment scientific objectives and the contract technical and environmental specifications and interface control documents. This effort includes the following:

(1) Perform design and analysis of all electronic circuitry.

(2) Perform breadboard testing of all electronic circuitry.

(3) Prepare drawings defining the electronic and packaging design.

(4) Prepare procurement specifications.

(5) Participate in meetings and presentations including interface meetings.

(6) Provide support to drafting in the form of detailed designs.

(7) Provide engineering test procedures for all electronic modules, subassemblies and assemblies.

(8) Perform evaluation studies with the engineering model to assure that the technical, environmental and interface requirements have been met.

5.3.( ).2 Engineering Testing

Work with the Manufacturing and Quality Control Department, provide electrical checkout of all Prototype and Flight electronic hardware using test procedures. This task includes:

(1) Checkout of all analog and digital modules.

(2) Alignment of modules.

(3) Determination of any malfunction and initiation of any action necessary to dispose of, correct, and report malfunction.

(4) Checkout and align all assemblies and instruments.

(5) Design, fabricate and test any test fixtures, cables and test equipment necessary to support electrical checkout.

(6) Participate as required in the acceptance and qualification test programs.

(7) Support Reliability in failure analysis.

5.3.( ).3 Design Drafting

Provide all drafting services and materials to completely detail the in-house design. This task includes the following:

(1) Provide drafting for electrical and mechanical drawings.

(2) Participate in the engineering drawing release activity in accordance with established policy.

(3) Incorporate all ECOs onto the required drawings.

(4) Provide and maintain a current drawing tree.

5.3.( ).4 Support to Production

Provide support to the Manufacturing Department to enable an efficient transition from the design phase of the program to the manufacturing phase. The following effort is included:

(1) Design special tooling.

(2) Design, assemble and test manufacturing test fixtures.

(3) Upon request, assist on any manufacturing problems related to the electrical design.

(4) Develop procedures and processes as required.

(5) Initiate ECOs as necessary resulting from manufacturing problems.

(6) Interpret manufacturing drawings.

(7) Participate on Material Review Board actions.

(8) Participate in evaluation of vendor performance.

(9) Assist as required in solving any vendor manufacturing problems.

5.3.( ).5 Program and Subcontract Support

Provide technical support of the program office as required. This task includes:

(1) Prepare data for inclusion into contract required documentation.

(2) Evaluate design approaches and prepare inputs to design reviews and interface documents.

(3) Act as technical advisor in the preparation and pursuit of subcontract negotiations.

(4) Provide technical monitoring of subcontractor progress.

(5) Respond to technical directives and prepare ECPs as required.

5.3.( ).6 Ground Support Equipment

(1) Provide technical support in the design of GSE.

(2) Provide technical support in the testing of GSE.

5.4 Mechanical Engineering

5.4.1 Dimensional Model
5.4.2 Structural Thermal Model
5.4.3 Electrical Model
5.4.4 Prototype Model
5.4.5 Flight Model
5.4.6 Ground Support Equipment

5.4.( ).1 Mechanical Design

Design and develop the mechanical portion of the Experiment which

includes the Large Area Detector and the Bragg Spectrometer structures and the detailed mechanical elements such as the collimators. The tasks will include the following:

(1) Mechanical design and layout effort.

(2) Supervision of drafting effort.

(3) Maintenance of CG & weight details.

(4) Support model shop activity.

5.4.( ).2 <u>Engineering Testing</u>

(1) Conduct vibration testing of critical elements and the experimental structures.

(2) Design test fixtures.

(3) Conduct environmental tests on critical components and subassemblies.

5.4.( ).3 <u>Thermal and Structural Analysis</u>

(1) Construct a thermal flow diagram.

(2) Analyze the thermal properties of the various elements of the Experiment.

(3) Prepare a structural analysis.

5.4.( ).4 <u>Support to Production</u>

(1) Assist in any manufacturing problems related to design.

(2) Interpret engineering drawings.

(3) Participate in Material Review Board actions.

(4) Supervise assembly of critical components.

5.4.( ).5 <u>Program and Subcontract Support</u>

(1) Prepare data for inclusion into contract requiring documentation.

(2) Evaluate design approaches and prepare inputs to design reviews and interface documents.

(3) Act as technical advisor in the preparation and pursuit of subcontract negotiations.

(4) Provide technical monitoring of subcontract progress.

(5) Respond to technical directives and prepare ECPs as required.

5.4.( ).6 <u>Ground Support Equipment</u>

(1) Provide design for any required ground-handling equipment.

(2) Provide design of calibration devices required for ground checkout.

5.5 Systems Engineering

5.5.1 Dimensional Model	5.5.4 Prototype Model
5.5.2 Structural Thermal Model	5.5.5 Flight Model
5.5.3 Electrical Model	5.5.6 Ground Support Equipment

5.5.( ).1 <u>Systems Design</u>

Participate in the conceptual design effort to ensure that all reasonable design alternatives and tradeoffs have been evaluated. This task includes the following:

(1) Evaluate conceptually the instrument design.

(2) Perform spacecraft interface studies with particular emphasis on data-transfer characteristics.

(3) Accomplish and maintain system design.

(4) Prepare and maintain interface documentation.

5.5.( ).2 <u>System Testing</u>

Perform all necessary steps required to conduct systems-level tests. This task includes the following:

(1) Support of engineering tests.

(2) Procure vendor test facilities as required.

(3) Perform Qualification Tests on Prototype model.

(4) Perform Acceptance Tests on Flight model.

(5) Initiate failure reporting for any failures occurring during Qual. and Acceptance Tests.

(6) Support calibration activities.

5.5.( ).3 <u>Integration and Field Support</u>

Provide qualified personnel to support integration, testing and pre- and post-launch operations.

5.5.( ).4 Documentation Support

Provide technical information and written material in the preparation of contractual documentation. Working with other groups, review the documentation for approach, correctness, etc. Working with the personnel assigned to Specifications and Standards, make the below documentation available for submission:

(1) Qualification Test Plan.
(2) Qualification Test Procedure.
(3) Acceptance Test Plan.
(4) Acceptance Test Procedure.
(5) Instruction Manual.
(6) Mission Support Plan.
(7) Launch Support Plan.
(8) Procurement Specifications.
(9) Inputs to Final Report.

5.5.( ).5 Program Support

(1) Maintain liaison with NASA in terms of the system interface.
(2) Support NASA-sponsored meetings.
(3) Assist on subcontract monitoring.

5.6 Reliability

Reliability Engineering will perform the following tasks:

5.6.1 Documentation

(1) Review and approve design specifications.
(2) Review configuration control documentation.
(3) Prepare system FMECA.
(4) Prepare an assessment of system reliability.
(5) Provide for parts and materials review, selection and approval.

5.6.2 Failure Reporting and Analysis

(1) Provide for system test log coverage.

(2) Monitor tests for log usage.

(3) Prepare analyses and reports of all failures.

(4) Provide appropriate evaluation, corrective and preventive actions.

5.6.3 Program Support

(1) Provide required reporting.

(2) Maintain liaison with GSFC Reliability functions.

5.7 Quality Control

Perform the following engineering and inspection tasks:

5.7.1 Quality Control Engineering

(1) Perform source inspection.

(2) Monitor acceptance and qualification testing.

(3) Implement corrective action.

(4) Prepare Acceptance Data Package.

5.7.2 Quality Control Inspection

(1) Conduct incoming inspection.

(2) Conduct in-process inspection.

5.8 Manufacturing

5.8.1 Dimensional Model
5.8.2 Structural Thermal Model
5.8.3 Electrical Model
5.8.4 Prototype Model
5.8.5 Flight Model
5.8.6 Ground Support Equipment

The specific tasks within this work package are as follows:

5.8.( ).1 Manufacturing Engineering

(1) Provide engineering support to all phases of the Manufacturing Operation.

(2) Provide tooling and fixtures.

(3) Provide supervision of the Manufacturing Operation.

5.8.( ).2 Manufacturing Control

(1) Provide detailed schedules for procurement, manufacturing, assembly, and inspection.

(2) Ensure availability of materials.

5.8.( ).3 <u>Electrical Fabrication</u>

(1) Perform electrical fabrication and assembly.

5.8.( ).4 <u>Mechanical Fabrication</u>

(1) Perform mechanical fabrication and assembly.

5.8.( ).5 <u>Material Fabrication</u>

(1) Provide potting and encapsulation.

(2) Fabricate printed circuit boards.

6.0 RELIABILITY

6.1 Reliability Program Plan

The reliability engineering program will be conducted in accordance with the details of this program plan. Reliability program review and control will be performed on a continuing basis to ensure compliance of the equipment with established program requirements.

6.2 Organization

The reliability engineering organization is shown in Figure 6-1 with a list of task responsibilities for each group. Figure 6-2 shows the position of the Reliability Engineering Organization in relationship to Company management.

6.3 Reference Documentation

The following reference documentation, to the extent covered in this program plan, will be used in the performance of the reliability tasks and in the control of hardware reliability:

(a) Government

NPC 250-1	"Reliability Program Plan for Systems"
MIL-HDBK-217A	"Reliability stress and Failure Rate Data for Electronic Systems

"Microelectronic Failure Rates, "December 1969, published by the Reliability Analysis Center, Rome Air Development Center

GSFC S-450-P-4A	"GSFC Specification for Screening of High Usage Electronic Parts . . . "
GSFC S-450-P-3A	"GSFC Specification for Screening of Semiconductors . . . "
GSFC-PPL-11	"Preferred Parts List" NASA/ Goddard Space Flight Center

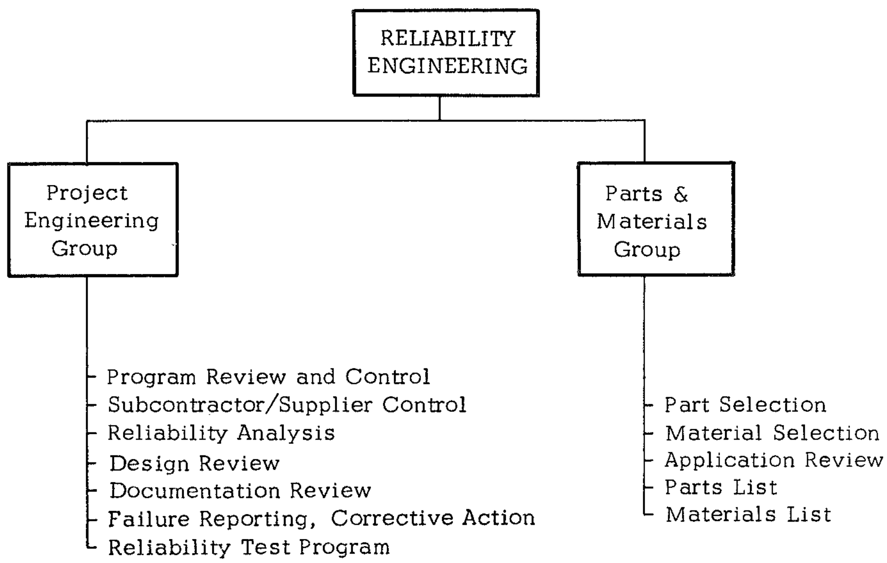


Figure 6-1. Reliability Engineering Organization

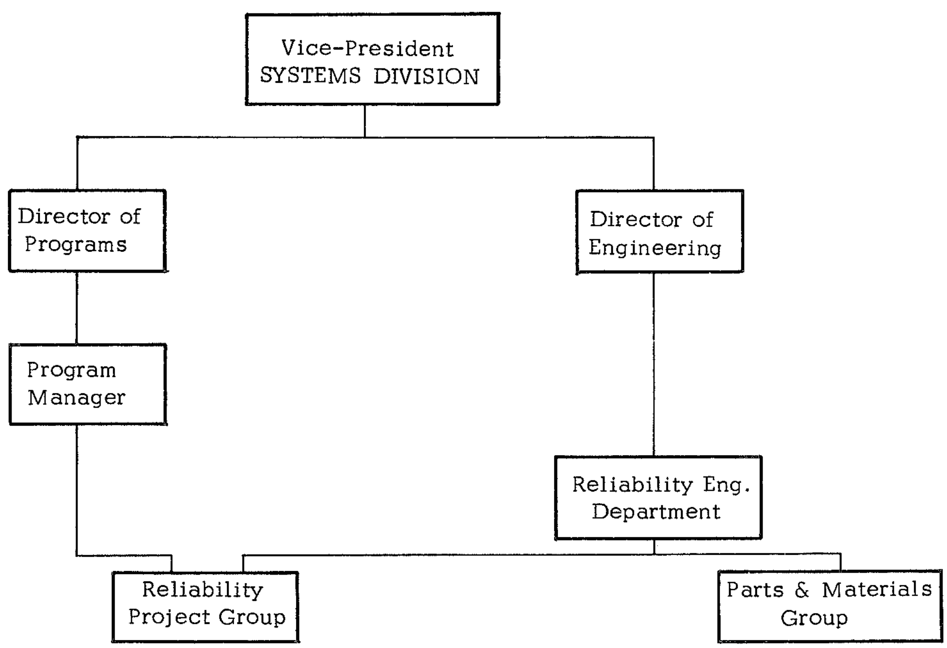


Figure 6-2. Reliability Relationship to Upper Management

(b) AS&E

R-8.1	"Electronic Part Derating Policy"
R-10	"Reliability Failure Reporting, Analysis and Corrective Action Procedure"
R-11	"Reliability Equipment Log Procedure"

6.4 Program Review and Control

The reliability program will be performed in accordance with a program milestone chart designed for the purpose. Continuous program monitoring will be established to assure meeting program milestones so that tasks are performed in accordance with existing schedules. The milestone chart will be periodically updated to reflect the relationship of the reliability task effort to the overall program progress.

Subcontractor/Supplier Control

AS&E will be responsible for ensuring that the reliability of system elements obtained from subcontractors and suppliers will meet the reliability requirements of the overall system. All subcontracts will include provisions for review and evaluation of the subcontractor's reliability effort by AS&E.

6.5 Malfunction, Failure Reporting and Corrective Action

AS&E Failure Report Procedure, R-10, has proven to be an established closed-loop system for reporting failures, performance of failure analysis, for ensuring proper corrective action for all failures, and providing a record of action taken in order to prevent future occurrences of the malfunctions and deficiencies which are discovered. Failures occurring from the start of the first functional test of an assembly of the engineering model through mission to power-turn-off will be reported to customer on GSFC

Form 4-2.

6.6 Maintainability

Consideration will be given throughout the program to assure the maintainability of the system by careful control of design, productability, fabrication, operation, testing, and handling.

6.7 Parts and Materials Program

The parts and materials group within the Reliability Department has the sole responsibility within the AS&E organization for approving all parts and materials to be used in equipment manufactured by AS&E or any of its subcontractors for application under NASA contracts (See Figure 6-1).

The parts and materials program will be conducted in accordance with established AS&E Reliability practices based upon past experience with NASA high reliability programs including the ATM Apollo Application Program, which includes a Control and Display Unit in crew bay, the OSO-G Satellite program, the SAS-A Explorer Satellite, and the Lunar Orbiter X-Ray and Alpha Particle Experiments. On these programs, extensive experience has been acquired in relation to selection of parts, covering determination of screening, burn-in, and other specifications, and to materials where outgassing characteristics are of primary importance.

Standard practice dictates that Reliability participates in the review and sign-off of all drawings, specifications, drawing changes, and test procedures, and must approve all procurement documents for parts and materials.

Parts Selection

Within delivery and design constraints, the criteria established

for part selection, in descending order of perference are:

> "NASA/Goddard Preferred Parts List, PPL-11
>
> "Military Established Reliability
>
> "Parts screened in accordance with Goddard or Contractor-prepared/Goddard approved screening specifications".

Supplier Selection

Qualified sources of supply of parts will be selected according to the order of precedence established for Parts Selection. Where non-standard parts are planned for design into the system, NSPAR (Non-Standard Parts Approval Requests) will be submitted to NASA/GSFC Project Manager with required information at least 30 days before purchase order initiation. If approval of the NSPAR is not granted, then NASA/GSFC will propose an acceptable alternate to AS&E. If disposition of the NSPAR is not received within 30 days after submittal, approval will be automatic. Status of all outstanding problem parts will be reported in the Monthly Progress Reports.

Parts Derating

The derating criteria described in Appendix B of the Statement of Work imposes demands which are in direct conflict with the tight volume restrictions required for the program. AS&E, therefore, proposes that part derating be performed in accordance with AS&E procedure R-8-1, "Electronic Part Derating Policy." This document describes the in-house techniques accepted on all its high reliability NASA programs. It has a proven record of established reliability on these programs. Moreover, since AS&E design engineers are completely familiar with this document there sill be no need for readjusting to a new standard.

Parts Screening 10A

Electronic Devices will be screened in accordance with: AS&E established screening specifications.

Copies of test reports or summaries of screening results will be submitted as required to the GSFC Project Manager.

Materials Selection

Experience gained by AS&E on other high reliability programs with reference to total volatiles, vapor condensable materials, flammability and toxicity characteristics will be utilized in selecting materials. With reference to metals, corrosion resistant steels and wrought aluminum alloys will be used except where special metals are needed for specific design functions. Cadmium or zinc will not be used for flight hardware. Tin will be permitted only where small areas are exposed, or on surfaces which will subsequently be soldered.

Where non-standard materials of any generic group covered in GSFC PPL-11 is considered for use, AS&E will submit on NSPAR with pertinent data to the technical officer at least 30 days prior to purchase order initiation. If approval of a deviation is not granted, then NASA/GSFC will propose an acceptalbe alternate item to AS&E. If disposition of the request for deviation is not received within 30 days after submittal, approval will be automatic. Status of all outstanding problem non-metallic materials will be reported in the Monthly Progress Reports.

Parts and Materials Lists

Approved Parts and Materials Lists will be prepared by AS&E. Preliminary lists of all parts and materials proposed for use will be

submitted 3 weeks before first design review. Data sheets and internal specifications will be submitted for review, and a final revision will be submitted with the design drawing data package. The Parts List will identify the part by generic name, part type, applicable specifications, additional requirements, manufacturer, and any other pertinent remarks or restrictions. The Materials List will identify the material by generic description, specifications, and where applicable, trade name, manufacturer, cure cycles, and limitations and restrictions. Surface area or weight will be included on those items where test data indecate characteristics wherein this information is significant.

Implementation of Parts and Materials Program

This program is established to assure review and approval of all parts and materials by the contractor's reliability organization. Responsibility for the preparation, monitoring, and securing approval of the Parts and Materials Lists will be assumed by the Reliability Department.

6.8 Reliability Test Program and Equipment Logs

The objective of the reliability test program is directed toward assessing the performance capabilities of the hardware and toward identification of potential failures which are not revealed in design reviews. Engineering analysis will be performed to the extent necessary to verify the existence of incipient failures. To accomplish this objective, AS&E's Reliability Department will review and approve all test plans, procedures and specifications that are prepared for development, qualification and acceptance testing of subassemblies, assemblies and the system. In addition, Reliability will monitor all such tests, and review and evaluate the test results.

An equipment log precedure, R-11, will be implemented for each system at hardware integration. These logs will be maintained with the hardware, will be available for customer review and will be submitted to customer as part of the data acceptance package.

6.9 Reliability Progress Reports

These reports covering the status of the Reliability Progess Plan and effort will be prepared and submitted monthly.

7.0 QUALITY CONTROL

AS&E's Quality Control System complies with the requirements of NPC 200-2 as indicated by the Quality Assurance Survey (QASR 68-09) conducted by NASA Goddard Space Flight Center during December 1968.

The Quality Control Program for this contractual effort will be initiated with the submission of a Quality Control Program Plan which will set forth the requirements necessary to insure that the AS&E/MIT experiment will meet the quality requirements of the contract. This plan provides the necessary policy direction and task definition for the establishment and maintenance of an effective QC system throughout the design, development, fabrication, assembly, inspection, test and checkout phases of the contract. AS&E Quality Control will also maintain surveillance over the activities of subcontracts. This continuing activity of monitoring and evaluation sub-contracts performance within established QC policies will provide the assurance that the prescribed level of quality will be met.

A QC manual which defines methods and procedures used by AS&E to assure an effective and economical system of maintaining product quality is in existence and has been approved by the Executive Vice President. The basic company policy is to deliver products meeting all specified and implied standards of performance. reliability and quality

The following summarizes the responsiblity of each functional group of the QC Department.

7.1 Mechanical, Electrical and In-Process Inspection

The inspection groups are responsible for the extent and method of examination given to purchased parts, assemblies, and materials.

7.2 Calibration Group

The calibration group maintains a laboratory of dimensional, electrical, and electronic reference and working standards. It also provides for instrument calibration and repair and offers technical support in the area of measurement theory and practices.

7.3 Quality Control Systems

The Quality Control System Group prepares, issues, and audits appropriate QC standards, policies, and procedures. The group also supports other QC activities in the area of the definition of Process Controls and acceptance rejection criteria.

7.4 QC Projects

A senior QC engineer will be responsible for directing all quality activity during the Engineering and Manufacturing phases for this program. The major tasks performed by the Senior QC Engineer are:

(a) Develop initial quality planning and provide a QC plan for customer approval.

(b) Review customer specifications.

(c) Review test plans and procedures.

(d) Review procurement request for inclusion of QC requirements

(e) Perform vendor surveys, source inspections and related vendor control activities.

(f) Control Material Review Board activities.

8.0 PROGRAM DOCUMENTATION AND CONFIGURATION CONTROL

8.1 Documentation Plan

AS&E shall determine the type style and format of each individual document. If NASA/GSFC specified type and format results in no additional cost and scheduling, the NASA/GSFC type and format shall be used.

Classification

Data required shall be of three categories. Type I data shall be submitted to NASA/GSFC for approval. Implementation of Type I documentation shall not proceed until after approval by NASA or until 20 days after receipt by NASA/GSFC, whichever is earlier. NASA approval is considered to be granted if AS&E has not received written notice of disapproval within 20 days after receipt of the document by GSFC. Type II data shall be submitted for coordination, surveillance, information review, and/or management control. Type III data shall be retained by AS&E. Insofar as practicable, AS&E's own internal documents shall be utilized to meet the requirements specified herein.

Data Identification

The applicable paragraph of the Statement of Work or its exhibits shall be stated in the letter of transmittal for the document.

Revision, Amendments, and Additions

In preparing Type I and Type II documentation which will require periodic revision, AS&E shall not re-submit the entire document but shall submit revised, amended, or additional pages as appropriate. Accompanying these pages will be an instruction page detailing the exact means for effecting the revision or amendment. The provisions of the paragraph do not apply to specifications, drawings, etc., which have an established procedure for the processing of amendments and revisions.

Engineering Change Proposals (ECP)

ECP's shall be submitted, but only for changes to the baseline configuration having to do with interface with the spacecraft, safety, schedule, and scientific objectives. All other changes shall be controlled by AS&E's change control system as Type III documentation.

Engineering Drawings

Engineering Drawings shall be prepared to MIL-D-1000 category A. A Drawing Tree on Identured Assembly list shall be provided with each set of drawings.

8.2 Deliverable Documentation

The documentation to be delivered in performing this effort is listed in Table 8.1, Documentation Schedule, with the appropriate documentation type and submittal schedule. This documentation is described in subsequent paragraphs of this section.

Management Plan

A Management Plan shall be prepared to define the management organization and procedure to be used during the development, integration and operation of Experiment Hardware.

Acceptance Data Package

An acceptance data package shall be prepared for each end-item of experiment hardware. The package shall include:

(a) Equipment log.

(b) Engineering drawings.

(c) Report of actual weight and center of gravity.

(d) Material review records.

(e) Certificate of compliance that end-item meets baseline configuration. The applicable acceptance test procedure with data taken shall be included.

Table 8.1. Deliverable Documentation

Item	Document	Initial Submittal	Type
1.	Management Plan	With proposal	II
2.	Acceptance Data Package (Prot & Flight Hdw.	With delivery of applicable hardware	II
3.	Input to Interface Document	As required	I
4.	Qualification Test Plan (Proto)	45 days prior to test	I
5.	Acceptance Test Plan (Flight)	45 days prior to test	I
6.	Mission Support Plan	6 months prior to launch	II
7.	Launch Support Plan	90 days prior to launch	II
8.	Engineering Drawing and Tree	At Design Review, with delivery of applicable hardware	II
9.	Inspection Plan	45 days after contract award	I
10.	Process Control Procedures	As required	II
11.	Reliability Program Plan	With Proposal	II

Table 8.1. Deliverable Documentation (Cont'd)

Item	Document	Initial Submittal	Type
12.	Design Review Minutes (NPC 250-1 Para. 3.6.1)	As required	II
13.	Malfunction Reports	As required	I
14.	Failure Analyses	As required	II
15.	Status Report of Malfunctions	As required	II
16.	Parts Spec. Control Drawings	As required	II
17.	Materials Lists & Parts Lists	3 weeks prior to first design review	I
18.	Non-Standard Part Request	As required	I
19.	Deviations From Screening Specs.	As required	I
20.	Summaries of Screening Results	As required	II
21.	Monthly Progress Report	Every month	II
22.	Project Final Report	By 31 December 1974	

(h) Certificate of flight worthiness.

(i) Copy of all applicable failure reports.

(j) Form DD250.

Equipment Logs

The format and content shall be in accordance with AS&E's standard practice.

Failure Reports

Failure reports will be prepared on all failures that occur during qualification and acceptance testing at the system level.

Interface Documentation

An Interface Document approved by the Netherlands Program Manager, AS&E, and the GSFC Project Manager, will be provided and updated by the Netherlands Consortium spacecraft contractor. It will define the requirements placed on the spacecraft by the experiment and specific data on each interaction, including telemetry format, data storage and command functions. Changes of this document after the Goddard conducted Design Review can only be made by mutual agreement of the Netherlands Program Manager, Goddard Project Manager and the AS&E Experiment Principal Investigator.

Monthly Progress Reports

The contractor shall provide monthly progress reports.

Qualification Test Plan for Prototype

A plan defining all systems-level and environmental tests required to qualify the prototype experiment design shall be submitted to the NASA/GSFC Project Manager for approval 45 days prior to start of the test program.

Acceptance Test Plan for Flight Unit

A plan defining all systems-level and environmental tests required

to verify the experiment flight worthiness shall be submitted to the NASA/GSFC Project Manager for approval 45 days prior to start of the test program.

Mission Support Plan

All experiment mission support requirements shall be submitted to the NASA/GSFC Project Manager six months prior to the ANS launch.

Launch Support Plan

A plan which defines all experiment Launch requirements and how they will be supported shall be submitted to NASA/GSFC Project Manager 90 days before spacecraft launch operations are initiated.

Quality Assurance Documentation

The following Quality Assurance Documentation shall be provided in accordance with the Statement of Work.

(a) Reliability Program Plan
(b) Design Review Minutes
(c) (NPC 250-1 Para. 3.6.1).
(d) Malfunction Reports.
(e) Failure Analyses - System Level
(f) Status Report of Malfunctions.

PART III. PRELIMINARY DESIGN DRAWINGS AND PERT NETWORK

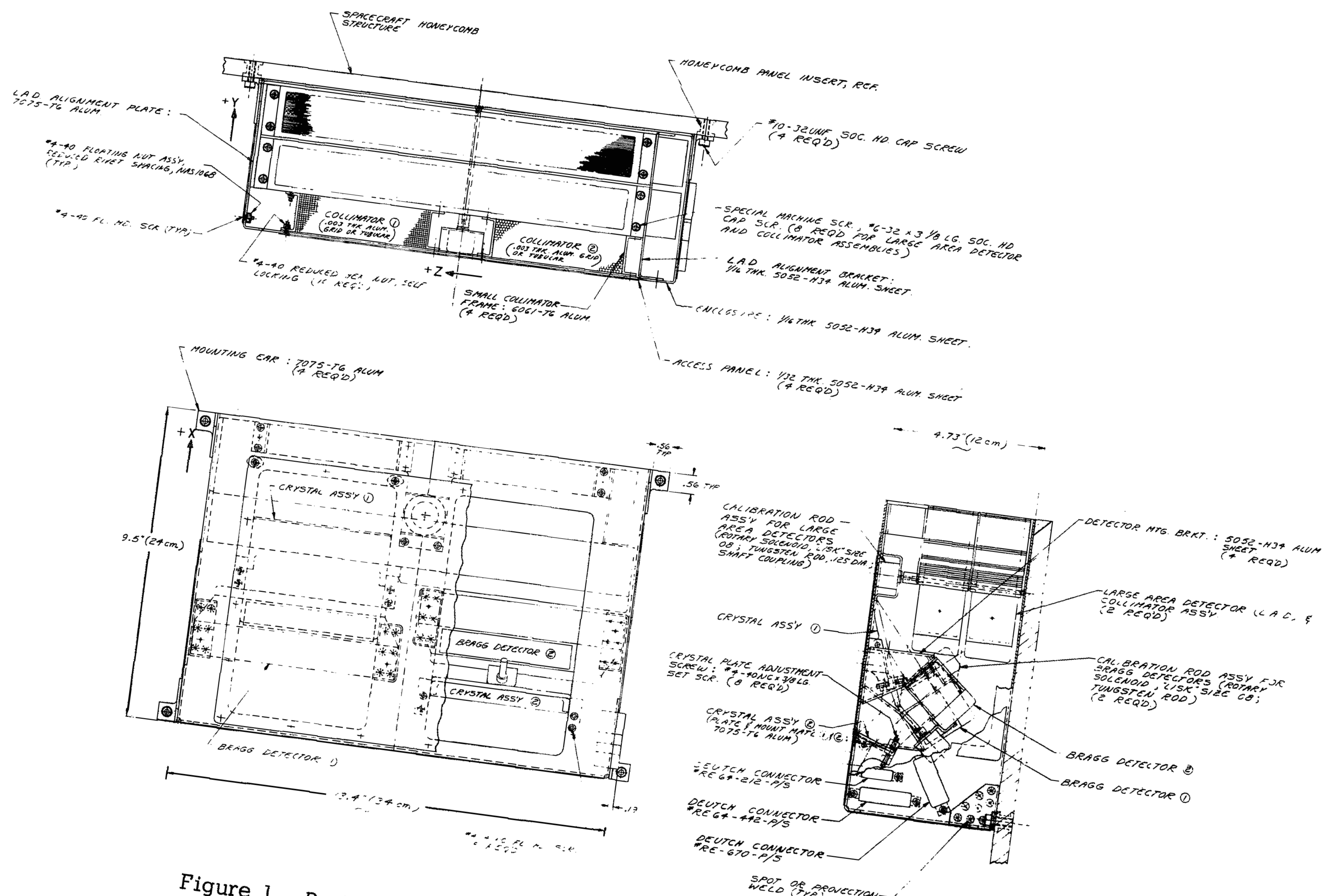


Figure 1. Preliminary Structural-Thermal Model for ANS (SK 135-003)

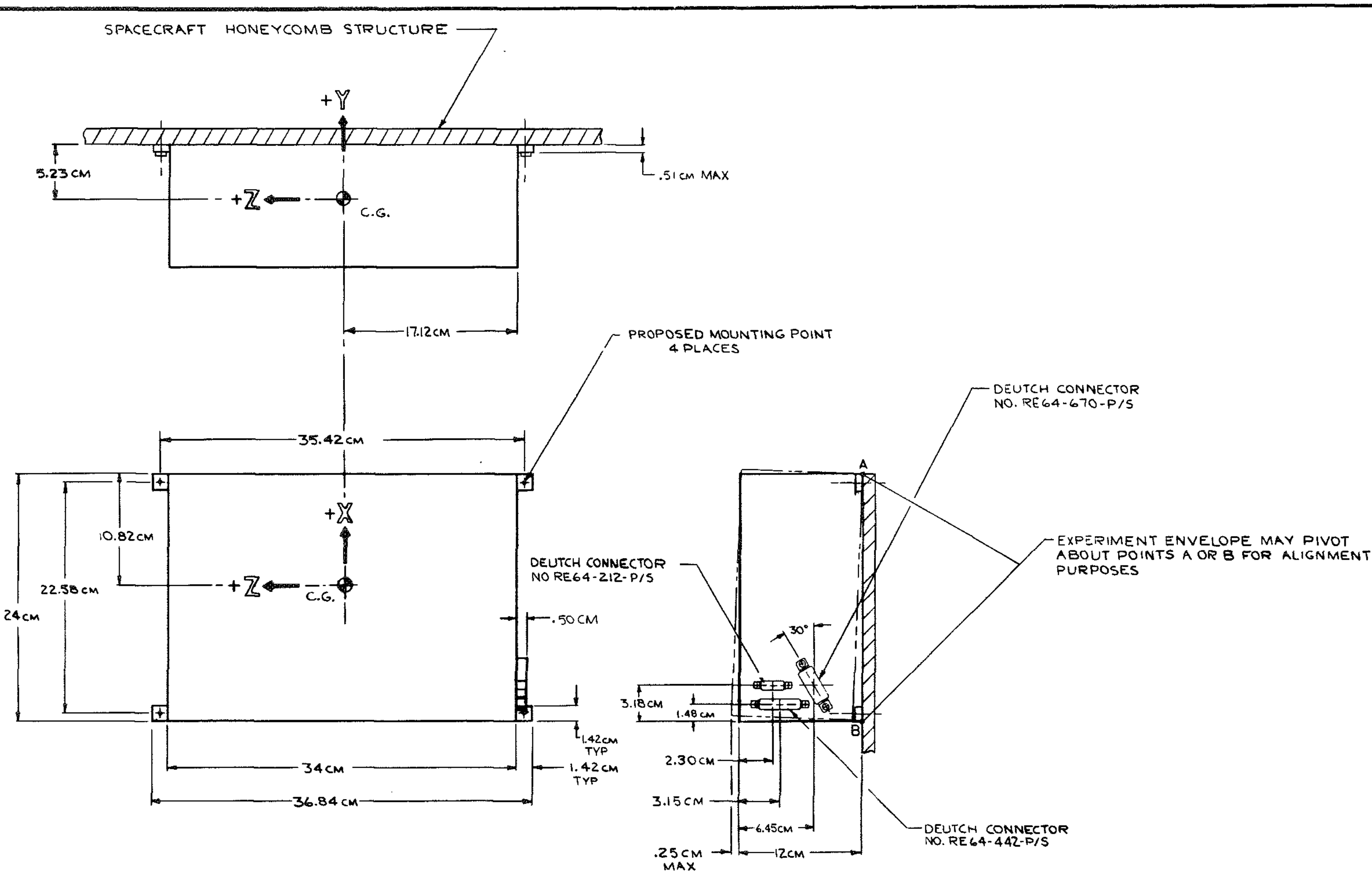


Figure 2. Preliminary Interface Control Drawing for ANS (SK 135-113, Rev. A)

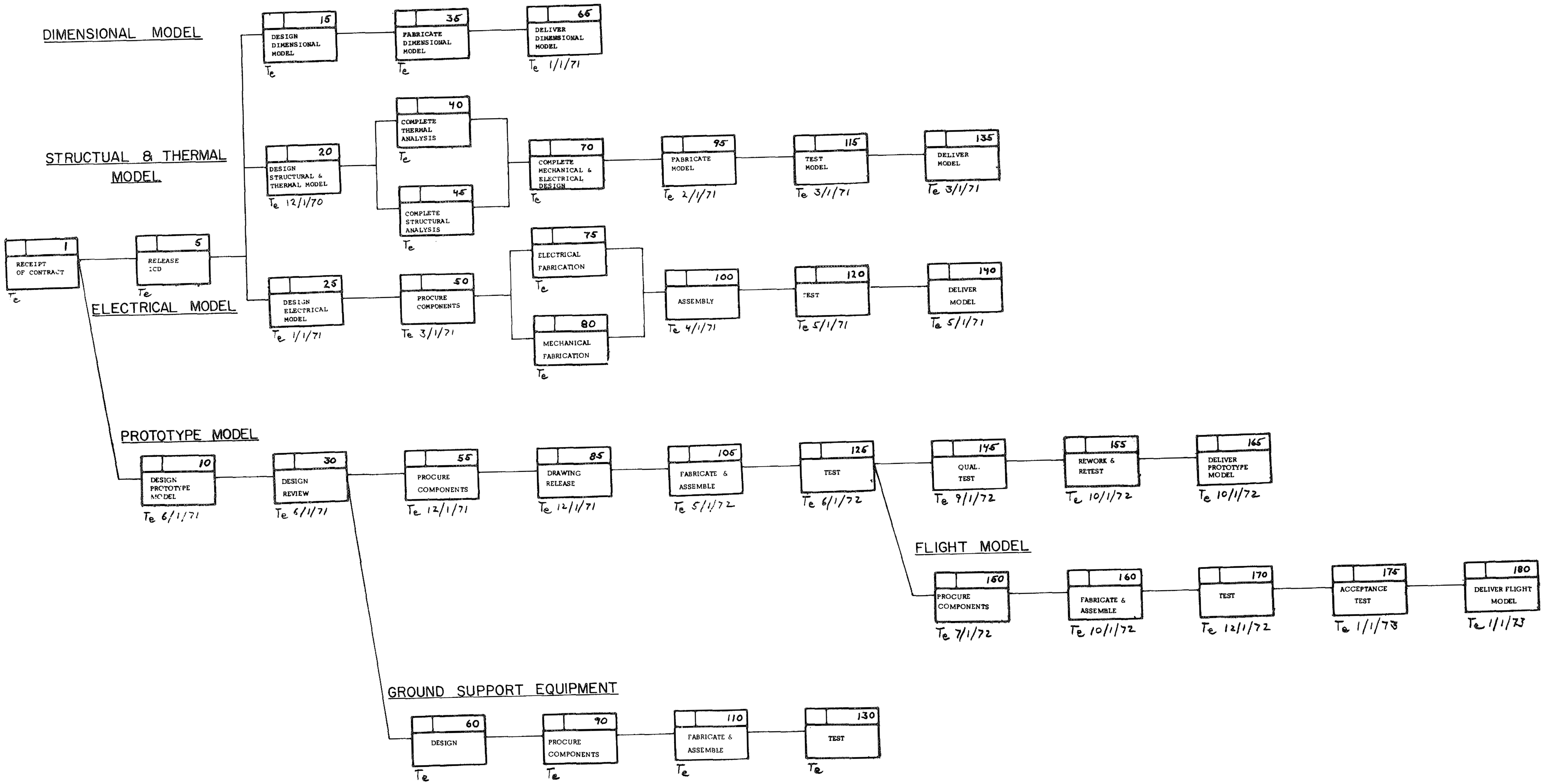


Figure 3. Preliminary Schedule, ANS Program PERT Network